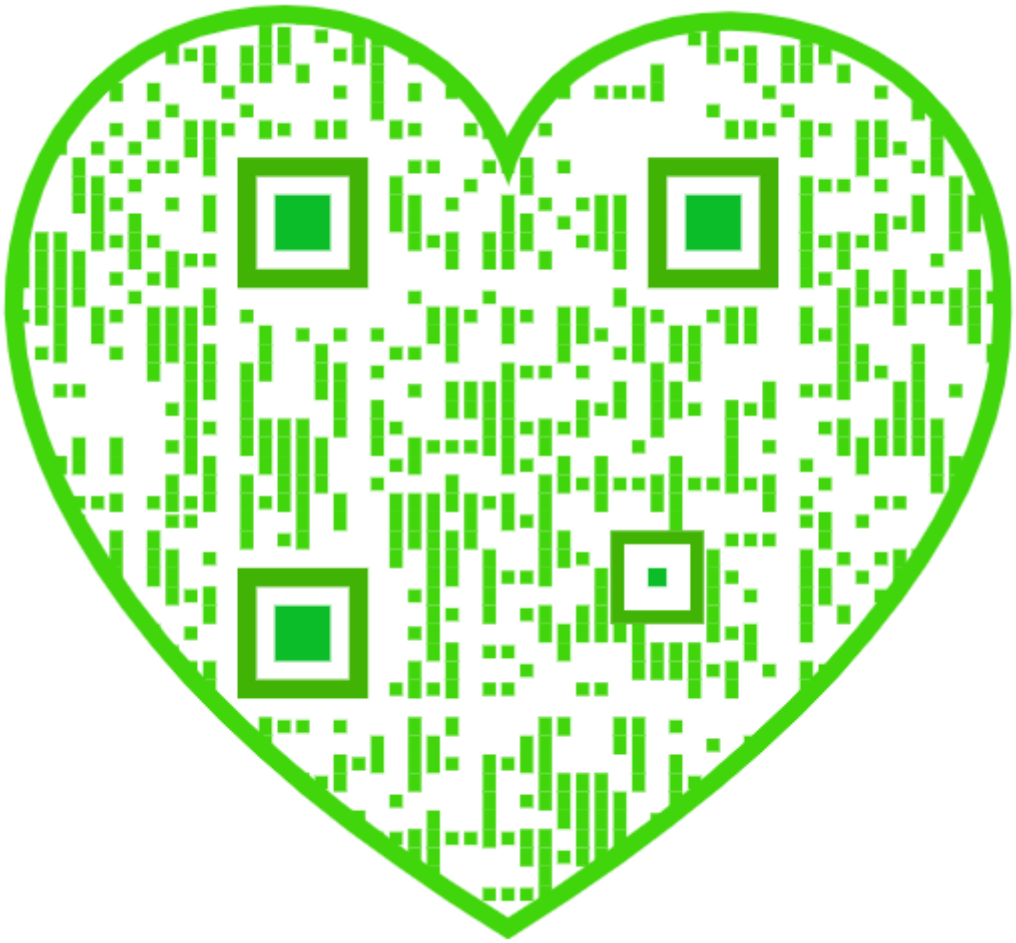
# HANDBOOK
ON
# THE STEAM ENGINE

*HAEDER & POWLES*

UNIVERSITY OF TORONTO
3 1761 00847642 6



E.C.A. Allcut



Presented to
The Library
of the
University of Toronto
by
Professor E.A.Allcut

**Castings in Bronze, Brass and Gun and White Metals, Machined if required.**

ROLLED PHOSPHOR BRONZE, Strip and Sheet, for Air Pump Valves, Eccentric Strap Liners, etc.

*SPRING WIRE and TELEPHONE WIRE.*

# THE PHOSPHOR BRONZE CO.,

LIMITED,

**87, Sumner Street, Southwark, London, S.E.**

*And at BIRMINGHAM.*

Sole Makers of the "VULCAN"

"COG WHEEL" and Brands of

## "PHOSPHOR BRONZE,"

The best and most durable Alloys for Slide Valves, Bearings, Bushes, Eccentric Straps, and other parts of Machinery exposed to friction and wear ; Pump Rods, Pumps, Piston Rings, Pinions, Worm Wheels, Motor Gearing, etc.

## "DURO METAL"

(REGISTERED TRADE MARK).

Alloy B, specially adapted for BEARINGS for HOT-NECK ROLLS.

## CASTINGS

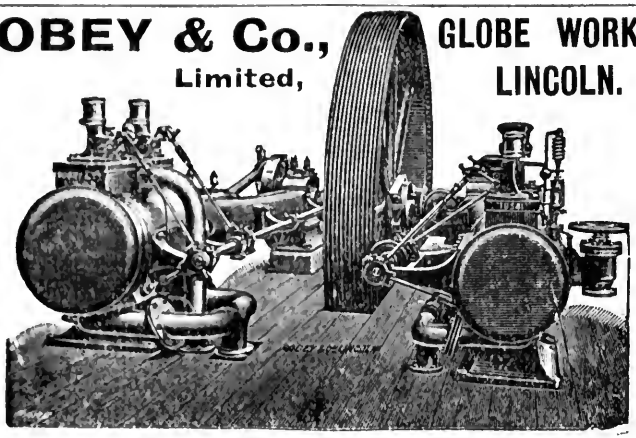
**In BRONZE, BRASS, GUN and WHITE METALS, in the Rough, or Machined, if required.**

**ROLLED AND DRAWN BRONZE, GERMAN SILVER, GUN METAL, TIN, WHITE METALS AND ALUMINIUM BRONZE ALLOYS.**

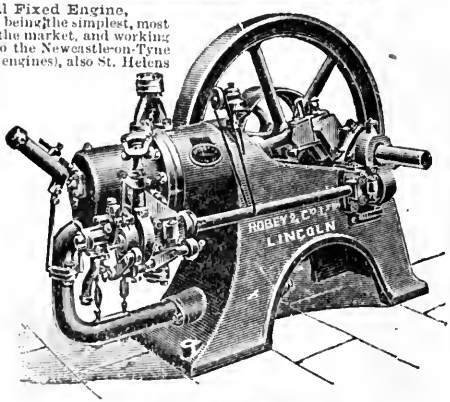
**PHOSPHOR TIN & PHOSPHOR COPPER, "Cog-Wheel" Brand.**

**Please specify the Manufacture of THE PHOSPHOR BRONZE CO., Ltd., of Southwark, London.**

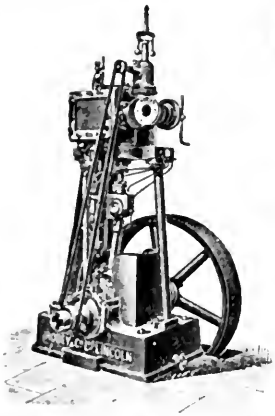
# ROBEY & Co., Limited, GLOBE WORKS, LINCOLN.



Coupled Compound Horizontal Fixed Engine, Fitted with Patent Trip Expansion Gear, being the simplest, most efficient, and most economical of any in the market, and working practically without friction. Supplied to the Newcastle-on-Tyne Central Electric Light Station (six large engines), also St. Helens Corporation, Brisbane Electric Tramways, &c., &c.




Improved Robey Gas Engine.

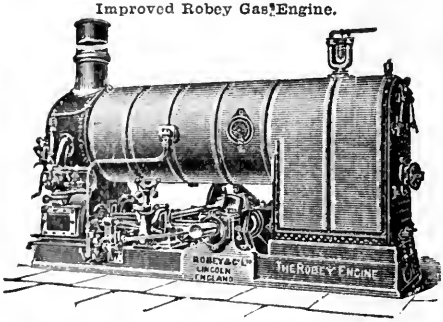


Open-front High-speed Vertical Engine, for electric lighting.

*All these Engines are specially Designed and Adapted for Electric Lighting.*

OFFICES AND SHOWROOMS—

**79, QUEEN VICTORIA STREET, E.C.**




Improved Compound "Robey" Undertype Engine.

# A HANDBOOK

ON THE

# STEAM ENGINE

WITH ESPECIAL REFERENCE TO

## SMALL AND MEDIUM-SIZED ENGINES

*FOR THE USE OF ENGINE MAKERS, MECHANICAL DRAUGHTSMEN, ENGINEERING STUDENTS, AND USERS OF STEAM POWER*


By HERMANN HAEDER, Civil Engineer

DUISBURG-ON-THE RHINE


*TRANSLATED FROM THE GERMAN, WITH CONSIDERABLE ADDITIONS AND ALTERATIONS*


By H. H. P. POWLES

ASSOC. MEMB. INST. C.E., M.I.M.E.


Third English Edition, Revised

LONDON

CROSBY LOCKWOOD AND SON

7, STATIONERS'-HALL COURT, LUDGATE HILL

1902

TEM
H

635040
10.5.56

BRADBURY, AGNEW, & CO. LD., PRINTERS,
LONDON AND TONBRIDGE.

## AUTHOR'S PREFACE TO FIRST EDITION.

In the present condition of the markets, makers must not occupy too much time in calculations or mathematical research, but collecting results from actual practice, must note them in a convenient form, though not as formulæ, since formulæ are only useful within certain limits, there always being a risk of error in calculation. If anyone compares the results of the formulæ of one writer with those of another, he will often find great discrepancies between them.

The present work aims at showing the results of practical experience. Letterpress has been reduced as much as possible, to allow of the introduction of numerous tables and drawings, these being the language of technical people.

To those firms and others who have supplied me with information, I return my best thanks. May the book and its method gain many friends!

---

## AUTHOR'S PREFACE TO SECOND EDITION.

The first edition of this book had such a favourable reception in technical circles, that within a year a second edition has been found necessary.

Encouraged by this success, I have spared neither trouble nor expense to extend the usefulness of the work, and with that object have introduced a large number of additional figures.

To the numerous technical friends who have favoured me with communications on the subject, I return my grateful thanks, with a request for them to assist me with further exchange of ideas.

# TRANSLATOR'S PREFACE.

In preparing this work for an English edition, the plan of the Author has been adhered to as closely as possible, the theoretical part being treated very briefly, and formulæ given only when necessary; whilst numerous tables of dimensions of engine-details, taken from actual examples, and accompanied by illustrations, are appended. These will afford means of comparing the results of Continental with those of English practice.

To the present Edition there have been added examples, with tables and illustrations, of standard types of English Engines by several well-known makers, who have kindly supplied for the purpose dimensions and drawings.

As thus adapted to our own practice, it is hoped that the present edition of the work will be found by many English Engineers, and Mechanical Draughtsmen in particular, to answer a very useful purpose, not as yet fulfilled by any other publication.

To make the tables as clear as possible, the dimensions have been given, in almost every case, uniformly in inches.

London, *May*, 1893.

---

## NOTE TO THIRD ENGLISH EDITION.

The whole work has again been carefully revised and the necessary corrections made. Some of the tables have been extended and some new matter added where necessary.

London, *August*, 1902.

# CONTENTS.


## INTRODUCTION.

PAGE

Historical Notes . . . . . 1—4

## SECTION I.

*TYPES OF STEAM ENGINES.*

Outline Diagrams showing Arrangements of Cylinders and Frames 5—14

## SECTION II.

*DETAILS OF STEAM ENGINES.*

Sections of Frames, Horizontal and Vertical, with Tables of Dimensions; Crank-shaft Bearings and Brasses; Cranks, Crank-discs, and Crank-shafts: Connecting-rods; Cross-heads; Pistons; Piston-rods; Cylinders; Steam-jackets; Glands and Stuffing-boxes; Valve Chests and Covers; Fly-wheels . . . 15—132

## SECTION III.

*GOVERNORS.*

Types with outline diagrams; Pendulum Governors; Crank-shaft Governors . . . . . 133—149

## SECTION IV.

*VALVE GEARS.*

Slide Valves, Simple, Meyer's; Piston Valves; Rider's Valves Valve Diagrams for Simple Valve Gears; Valve Gears with two Valves; Valve Rod Guides and Joints; Eccentrics; Mushroom and Double-beat Valves; Corliss Valves . . 150—270

PAGE

## SECTION V.

*CONDENSERS, AIR-PUMPS, AND FEED-PUMPS.*

Injector Condensers with Air Pumps, Vertical and Horizontal; Surface Condensers; Feed-water Heaters . . . 271—291

## SECTION VI.

*EXAMPLES OF ENGINES OF CONTINENTAL MAKE, FROM ACTUAL PRACTICE.*

Vertical, Horizontal, Compound; Floor Space occupied; Weights of Parts; Foundations . . . . . 292—316

## SECTION VII.

*PARTICULARS OF ENGINES BY ENGLISH MAKERS.*

Horizontal, Vertical, Undertype, Portable, Tandem and Coupled Compound . . . . . 317—353

## SECTION VIII.

*COMPOUND ENGINES.*

Outlines shewing arrangements of Cylinders; Leading Particulars; Proportion of Cylinder Volumes of Vertical and Compound Engines; Compound Paddle Engines . . . . . 354—371

## SECTION IX.

*INDICATOR AND INDICATOR DIAGRAMS.*

Types of Indicators; Reducing Gear; Examples from Actual Practice; Defects in Diagrams; Combined Diagrams . . . 372—386

## SECTION X.

*CALCULATIONS FOR POWER AND STEAM CONSUMPTION.*

Losses by Wire Drawing; Effect of Clearance; Friction; Calculations for Power of Compound Engines . . . . . 387—400

PAGE

SECTION XI.

*EFFECT OF INERTIA ON RECIPROCATING PARTS OF ENGINES* . . . . 401—409

SECTION XII.

*FRICTION BRAKE DYNAMOMETER* . 410—411

SECTION XIII.

*SUNDRY DETAILS.*

Special Reversing Gears; Barring Arrangements . . . 412—415

SECTION XIV.

*BOILERS.*

Cornish, Lancashire, Multitubular, Loco-type, Marine, Water-tube, Vertical; Boiler Seatings; Safety Valves; Feed Pumps . . 416—451

INDEX . . . . . 453

HERM. HAEDER, C.E., DUISBURG o/RH.

SUPPLIES

GENERAL and DETAIL DRAWINGS of STEAM ENGINES of the best types, with ordinary Slide-valve, Corliss-, and Drop-valve Gear. Also of CONDENSING PLANTS, with or without Cooling Arrangements for the Condensing Water. Unsurpassed, simple and effective. The highest vacuum. Smallest quantity of Water required. Patents in the principal Countries of the World.

# THE STEAM ENGINE.

## INTRODUCTION.

THE knowledge that steam could be made use of as a motive power is very old, but it was not until about the year 1685 that the first model of a steam-engine was made by Dionysius Papin, a native of Blois in France, based on the fact that if cold water was applied or admitted to an enclosed vessel containing steam, the steam was condensed, and a vacuum resulted. In 1699, Captain Savery employed this principle for raising water, and in 1705 Newcomen, of Dartmouth, in Devonshire, constructed the first steam-engine properly so called. This first example was employed for raising water, and was known as "The Atmospheric Engine:" fig. 1 shows the general arrangement.

*a*. The steam cylinder.
*b*. The piston.
*c*. The steam generator or boiler.
*d*. The cock for admitting steam to the cylinder.
*e*. The cold water reservoir.
*f*. The cold water or "injection" cock.
*g*. A valve opening outwards to allow steam to be blown through, but preventing air from entering the cylinder.
*h*. The main beam for transmitting the motion of the piston to the pump rod.
*i*. The pump rod.

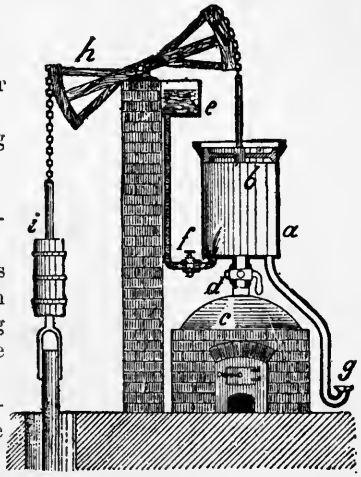



Fig. 1.—Newcomen's Atmospheric Engine.

The action of the engine is as follows :—In fig. 1 the weight of the pump rod, *i*, has brought the piston, *b*, to the top of the cylinder, the cylinder is then filled with steam from the boiler at atmospheric pressure through the cock, *d*, which is then closed. The cock, *f*, is now opened, and cold water from the tank, *e*, enters the cylinder in a jet ; the steam is condensed, and a vacuum produced below the piston. The atmospheric pressure above the piston forces the latter down to the bottom of the cylinder, at the same time raising the opposite end of the main beam, and with it the pump rod, *i*. By opening and closing the cocks, *d* and *f*, in succession, an alternate up and down movement is given to the piston.

James Watt introduced many improvements, especially the separate condensing chamber, in place of admitting the injection water into the cylinder, which tends to lower the temperature of the cylinder walls, and he remarked in one of his specifications "that the cylinder should be kept as hot as the steam that enters it." James Watt also invented mechanism for automatically opening and closing the valves, introduced the use of steam above atmospheric pressure, and discontinued the use of atmospheric pressure alone, by making use of the expansion of the steam for doing work on the piston. Watt's first engine was built in 1768. A year or two earlier, Smeaton had made many improvements ; but James Watt was amongst the first who really treated the steam-engine on a scientific basis.

Fig. 3 shows in diagram one of Boulton and Watt's condensing beam engines, working with a pressure of from 5 to 15 pounds on the square inch.

These early engines were invariably worked with low boiler pressures, and with condensation. High boiler pressures were regarded with distrust, and James Watt, although he gave attention to the idea, had strong prejudices against using high-pressure steam.

The first high-pressure engines using steam at 3 to 4 atmospheres were by Oliver Evans in America, 1786 to 1801, and Trevithick and Vivian in England, 1802.

The fact that the use of high pressures decreased the consumption of coal was soon recognised, and steam of 4 to 6 atmospheres was used, with and without condensation.

With high-pressure steam the advantage of expansion is very great. By using steam "expansively" is to be generally understood that the steam is admitted at high pressure for a short portion of the piston-stroke only, and then allowed to expand down to the end of the stroke, losing heat thereby in doing work. If the expansion is carried too far, the cooling becomes so great as to condense part of

the steam. In order to prevent the waste from this cause, and to prevent the range of temperature between the entering and exhaust steam, the expansion is now carried on in two or more cylinders of different capacities; and engines on this principle are called "compound," if with two cylinders; triple expansion, if with three; quadruple expansion, if with four. Sometimes they are named "continuous" expansion engines, whether with two or more cylinders; also, when with three cylinders, they are occasionally termed "tri-compound."

The earliest attempt at a compound engine seems to have been that of Jonathan Hornblower in 1781, although he does not seem to have had any idea of what is understood now by a "compound" engine. He used two cylinders of unequal size, A and B (fig. 2); the steam was admitted first to the smaller cylinder, B, above the piston. On the piston arriving at the bottom of the stroke, the communication between the cylinder and boiler was cut off, and a communication between top and bottom of the cylinder was opened by means of the pipe, Y, and cock, *b*. The piston then ascended by the weight of the pump-rod, X, and the steam displaced by the rising piston now filled the space below the piston. The cock, *b*, was then closed, and boiler steam admitted above the piston. The downstroke then commencing, the cock, *c*, opened the steam from the cylinder, B, then flowed into cylinder A, where it further expanded. On completion again of the downstroke, communication between upper and lower sides of the piston, A, was established, and the steam, after having done work on the upper side of the piston, passed to the lower side by means of the pipe, Z, and cock, *d*, during the downstroke; the steam eventually passed to the

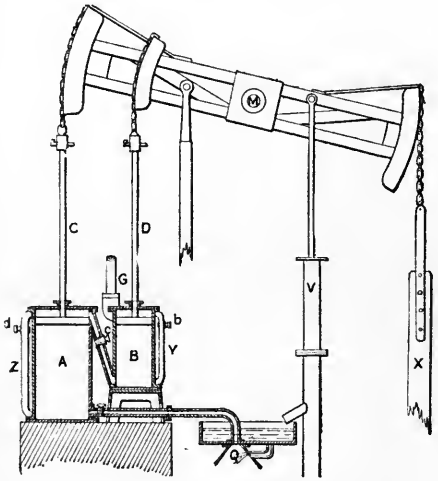



Fig. 2.—Hornblower's Engine.

condenser, Q. It will be seen that the engine was really "compound," but it does not seem to have been more economical than the simple engines of James Watt of the same date, and was rather complicated. An outline of this machine is shown in fig. 2. Hornblower's engine was single acting.

In 1804 Arthur Woolf made a two-cylinder high-pressure engine with a condenser, together with a water-tube boiler, and took out an English patent for the same. Woolf's engine was an improvement on Hornblower's, being more simple in construction and double acting. It appears that one of Woolf's best engines was tried for coal consumption against one of Watt's in Cornwall, and resulted greatly in favour of Woolf's engine, probably from his using higher pressure steam, and from his carrying the expansion down in two separate cylinders.

In 1850 John Elder much improved the compound engine, and brought it into successful use for marine engines.

The annexed table shows the development in saving of fuel ; the figures give the coal consumption in pounds per horse-power per hour.

| Atmospheric Engine. **Savery.** 1700 | Low-pressure Engine. **Watt.** 1768 | High-pressure Engine. **Evans.** 1804 | Double Cylinder Engine. **Woolf.** 1804 | Compound Engine. **Elder.** 1850—1891 | Triple Expansion Engine. 1880—1891 |
|---|---|---|---|---|---|
| 31 | 8·8 | 6·7 | 4·5 | 2·25 | 1·76 * |

It may appear that steam-engines have been brought to a high state of perfection, but it must be remembered that the efficiency of the best engines and boilers taken together is only about 15 per cent. of the theoretical value of the heat energy of the fuel.

* In a trial of a triple expansion marine engine by the Research Committee of the Institution of Mechanical Engineers in July, 1891, the consumption of coal per indicated horse power per hour was as low as 1·46 lbs.

# SECTION I.

## TYPES OF STEAM ENGINES.

**Beam Engine,** the original form as constructed by Boulton and Watt. This form owed its existence to the fact that all the earlier steam engines were used for pumping water, the beam forming a convenient means of attachment for the pump rods. Beam engines are still used for pumping, but are gradually giving way to more modern types.

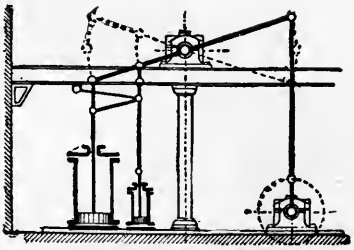
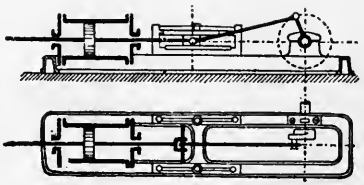


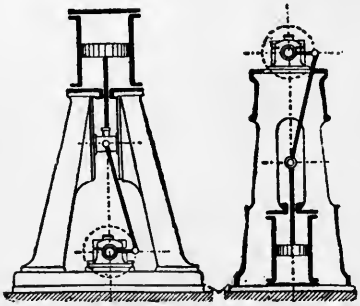
Fig. 3.—Beam Engine.

**Horizontal Engine,** with open frame cast iron bed-plate, a type much used for all sizes of engines for general purposes. The bed-plate frame is of U section, and is bolted down to a foundation of masonry or brickwork, the cylinder, main bearing and guides being bolted to the bed-plate.

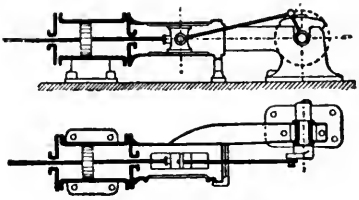


Figs. 4 and 5.—Horizontal Engine with Bed-Plate.

**Vertical Engine.**—A type now extensively used both for small and large engines; it has the advantage of occupying small floor space, and is not open to the objection so often put forward against horizontal engines,—that of the cylinder wearing oval. An endless number of varieties of this type are now in use, and it is the generally accepted type of marine screw-propeller engines.



Figs. 6 and 7.—Vertical Engines.



Figs. 8 and 9.—Girder Engine.

**Corliss Frame or Girder Engines.**—A type of horizontal engine now extensively used. Figs. 8 and 9 show an example with bored guides; they are also often made with flat-planed guides. In both cases the guides are formed in the main casting or girder which connects the cylinder to the main bearing. There are many varieties of this type.

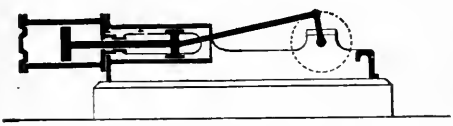


Fig. 10.—Self-contained Horizontal Engine.

**Self-contained Horizontal Engines,** with bent or slotted out cranks. This type, largely used for small power short-stroke engines, has the cylinder bolted on to the end of an open bed-plate, which is widened out at the other end to take both bearings of the crank-shaft, so that the flywheel may be keyed on either side. The guides are usually formed in the bed-plate, the boring out of the guides and facing of the end flange being done at the same setting.

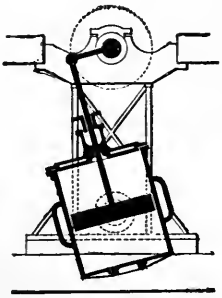


Fig. 11.—Oscillating Marine Engine.

**Oscillating Engines,** formerly much used as marine engines. Fig. 11 shows the usual type as made by Penn and others for driving paddle-wheels; this type has also been used for driving screw propellers, but is now almost superseded by the vertical type of marine engine.

**Trunk Engines.**—Fig. 12 shows an example of this type for driving a screw propeller as made by Penn. It has the advantage of being very compact and simple, but is open to the objection of the very large gland for the trunk, and that the trunk in its outward stroke is exposed to the cooling effect of the air. Very large engines of this type were formerly made. Two varieties are also shown in figs. 13 and 14.

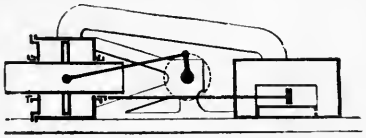
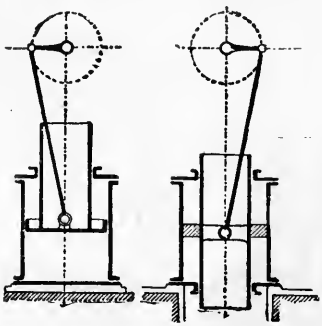
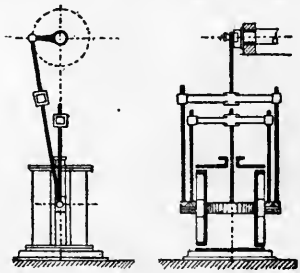


Fig. 12.—Penn's Trunk Engine.



Figs. 13 and 14.—Trunk Engines.

**Vertical Marine Engine,** old type by Maudslay. Arrangement to reduce height, but at the expense of introducing heavy reciprocating masses.



Figs. 15 and 16.—Maudslay's Marine Engine.

**Steeple Engine,** formerly, and still occasionally, used for driving paddle-wheels. A variety of this type has been used for small powers, and known as the Table Engine.

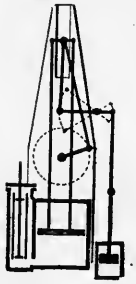


Fig. 17.—Steeple Engine.

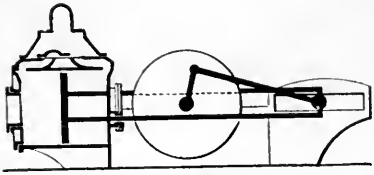


Fig. 18.—Bourne's Marine Engine.

**Bourne's** "return connecting-rod" engine, derived from the Steeple Engine, and used principally for driving screw propellers. There are two piston-rods in this engine, placed above and below the crank-shaft.

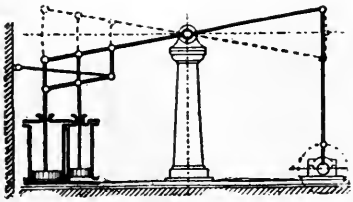


Fig. 19.—Woolf's Compound Beam Engine.

**Beam Engine, Woolf's Compound.** — Two unequal cylinders, side by side, at one end of the beam. Many pumping engines are of this type.

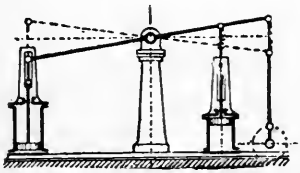


Fig. 20.—M'Naught's Compound Beam Engine.

**M'Naught's Compound Beam Engine.**—This system, consisting of a small cylinder (high pressure cylinder), placed at the opposite end of the beam to the larger cylinder used as a low-pressure cylinder, was introduced by M'Naught for increasing the power of existing engines. The high-pressure cylinder was the one added, the original cylinder being the low pressure cylinder. The power of the engine was thus increased by increase of boiler pressure and the addition of the new small cylinder, to which the boiler steam was admitted.

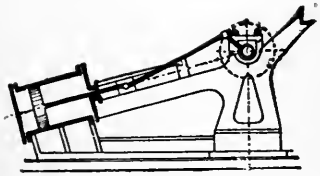


Fig. 21.—Inclined Frame Engine.

**Inclined Frame Engines,** now used extensively for paddle-steamers in several different varieties, usually compound engines.

**A Double-Cylinder Engine** variety derived from the above, with the cylinders inclined at an angle of about 45°, is occasionally used for driving rolling-mills in bar iron works.

Fig. 22.—Inclined Frame Engine.

A variety of compound engine, with inclined cylinders, is shown in fig. 23.

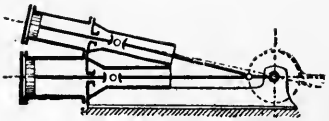


Fig. 23.—Inclined Cylinder Engine.

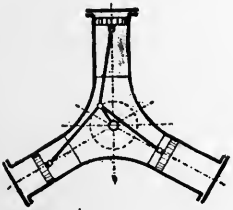


Fig. 24.—Radial Engine.

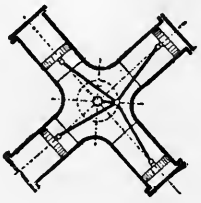


Fig. 25.—Four-Cylinder Radial Engine.

**Radial Engines.**—A modern type, of which there are many varieties. Fig. 24 shows Brotherhood's three-cylinder single-acting radial engine ; fig. 25, one with four cylinders. These are used for driving fans, steam-launches, and other purposes requiring speed and compactness.

**Willans' Central Valve Engine.**—One of the most modern types of engine, single-acting, compound or triple-expansion ; a special feature is the hollow piston-rod and central valve. Extensively used for driving dynamo-electric machines coupled direct on to the armature spindle. (See pages 348—352.)

Fig. 26.—Willans' Central Valve Engine.

**Various ways of arranging Cylinders and Cranks in Double and Three-cylinder, Compound, and Triple-expansion Engines.**—Outline diagrams.

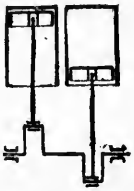


Fig. 27.—Double Cylinder, with cranks opposite or at 180 degrees.

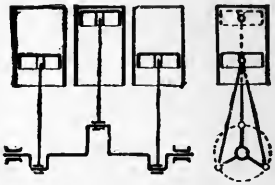


Fig. 28.—Three-cylinder Engine, with cranks at 120 degrees.

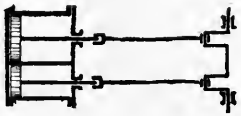


Fig. 29.—Compound Woolf Engine, with cranks together.

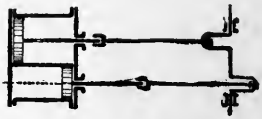


Fig. 30.—Compound Woolf Engine, with cranks opposite or at 180 degrees.

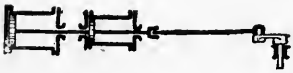


Fig. 31.—Compound Tandem Engine with receiver.

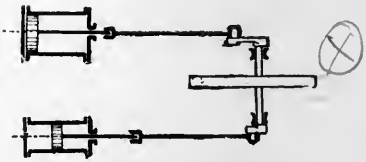


Fig. 32.—Compound Engine, with cylinders side by side with receiver; cranks at 90 degrees.

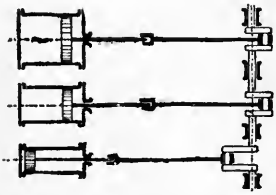


Fig. 33.—Triple Expansion Engine, with cylinders side by side; cranks at 120 degrees.

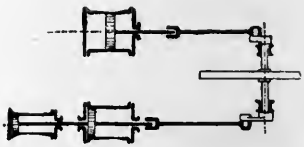


Fig. 34.—Triple Expansion Engine, semi-tandem; two cranks at 90 degrees.

**Action of Pistons and Cranks in Woolf, Compound, and Triple-expansion Engines.***—Outline diagrams.

A crank is shown to each piston, to enable the action to be clearly followed ; in reality there is only one crank shaft to each engine.

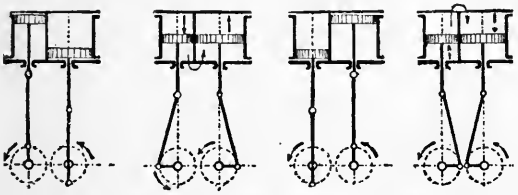


Fig. 35.—Woolf Engine, with cranks opposite (180°), without receiver.

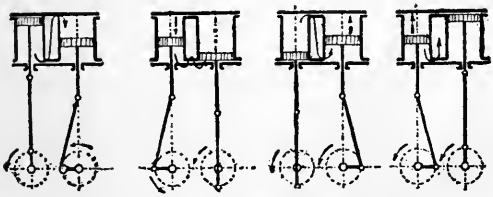


Fig. 36.—Compound Engine, with cranks at right angles, with receiver.

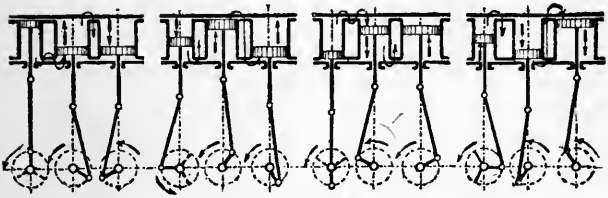


Fig. 37.—Triple Expansion Engine : cranks at 120 degrees, with two receivers.

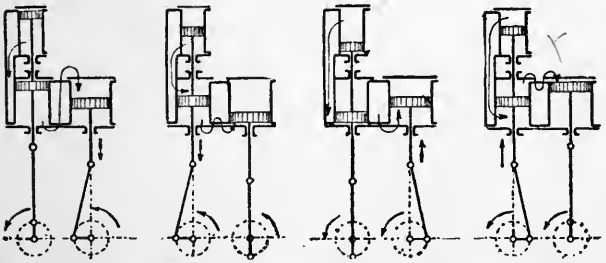


Fig. 38.—Semi-Tandem Triple-Expansion Engine, with two receivers.

* Further details of the action of these compound engines are given in the section on Compound Engines, page 350.

## Names of the Parts of a simple Steam Engine.

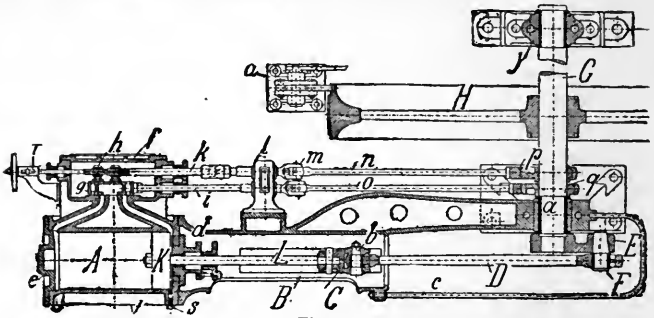



Fig. 39.

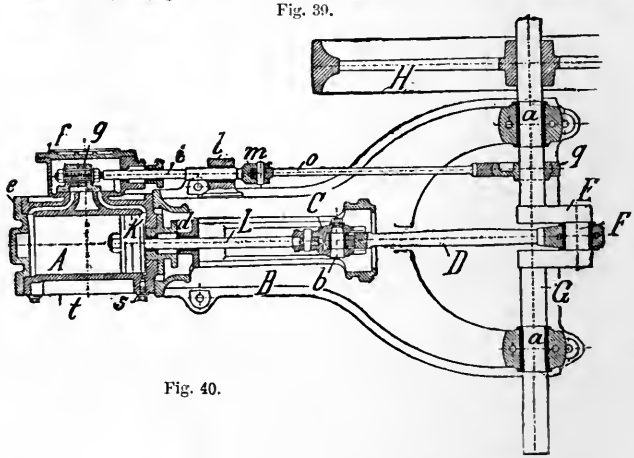



Fig. 40.

*A*. Cylinder.
*B*. Frame, bed, or bed plate.
*C*. Crosshead.
*D*. Connecting rod.
*E*. Crank.
*F*. Crank pin.
*G*. Crank shaft.
*H*. Fly wheel.
*J*. Outer bearing of crank shaft.
*K*. Piston.
*L*. Piston rod.
*a*. Crank shaft bearings, or main bearings.
*b*. Crosshead pin or gudgeon.
*c*. Safety rail round engine.
*d*. Front cylinder cover with stuffing box [and gland.
*e*. Back cylinder cover.
*f*. Valve chest, or steam chest.
*g*. Main valve or main slide.
*h*. Cut off valve or expansion valve.
*i*. Main valve rod or spindle.
*l*. Valve rod guides.
*m*. Valve rod joints.
*n*. Cut off valve eccentric rod.
*o*. Main valve eccentric rod.
*p*. Cut off valve eccentric.
*q*. Main valve eccentric. [expansion.
*r*. Hand adjustment for varying the
*s*. Bosses for indicator cocks.
*t*. Lagging, casing, or clothing.
*u*. Arrangement for turning the engine slowly round, "barring" arrangement.

## Notes and General Remarks.

The size or perhaps better the power of an engine may be estimated by the diameter of the cylinder, the length of the stroke and the boiler pressure. The merits may be judged by the general design, workmanship, materials used, the construction of connecting rod ends, crosshead, crank shaft bearings, and by the nature of the valve gear.

The proportion of stroke to cylinder diameter varies from 1.5 to 2.0 in ordinary engines for driving plants of machinery, and in special high speed engines from .75 to 1.25.

The steam engine maker must consider well before making a series of engines of one type, how best to make the minimum number of patterns serve for different sizes or powers required, and it is important to see that the parts are as far as possible symmetrical about the centre line, in order that engines may be readily built right or left-handed, in short before making either drawings or patterns, all possible dimensions should be tabulated out clearly, a few skeleton outlines being made for the different sizes showing centre lines only, the details such as pistons, crossheads, crank pins, main bearings, etc. can then be designed and a general drawing of each size prepared; from which the larger patterns can be made.

The most convenient starting points are obviously the diameter of the cylinder and the length of the stroke, then follow the speed, the maximum steam pressure and the subordinate details.

In making a set of drawings for a steam engine; for example of the horizontal girder type; the following method will be found both convenient and quick. Draw the centre line for the cylinder in plan and also the centre line for the crank shaft at right angles to the same, then from the table of dimensions draw in the crank pin where the two centre lines cross, on the centre line of crank shaft the width of the crank may then be set out which will give the position of the main bearing, the width of the same being taken from the tables; the same two centre lines are then drawn in elevation, and a circle for the path of the crank pin centre, the length of the connecting rod from the tables, will give the three positions of crosshead pin centre, an outline of crosshead at the two extreme positions will give the necessary length and positions of the guide surfaces for the crosshead slippers, the piston rod gland then drawn in will give the necessary clearance between it and the end of the crosshead boss. The stuffing box and cylinder cover then added will enable the position of the

cylinder to be determined ; the remainder of the engine may then be filled in on the same principle, remembering that in all machine designing, whether they be steam engines or other machines of more or less special character, it is always well to have in view the fact that the complete machine to be designed is composed of a number of elementary parts or "units," which have to be brought together in a practical form, and in order to save time and labour all these "units" should be thoroughly worked out before the attempt is made to work out the complete machine.* It is, however, obvious that even elementary parts require modification, but the more thoroughly the smaller details are worked out, the less will be the labour and thought necessary to produce a complete machine for any special purpose. Speaking of the designing of steam engines of small powers, where a large number have to be made of few different sizes, the most successful makers have always been those who keep all the possible elementary parts in stock, this system enabling the cost of production to be greatly decreased, and leaving a margin for better design, material, and workmanship than is possible when each part is only made when actually wanted. Careful proportion of parts is not all that is wanted ; a detail that may work out well in one manufactory will not do so well in another. The designer must know the capabilities of the factory, nay, even the capabilities of the heads of the different workshops, before he can produce designs capable of being carried out so that the works may be run at their maximum efficiency.

---

* To many, these remarks may seem superfluous, but from neglect of these first principles of machine design much time is often lost in the drawing office.

# SECTION II.

## DETAILS OF STEAM ENGINES.

THE following leading points in steam engine design and construction are important.

Ample strength—it is not sufficient to trust to calculation alone but to compare calculated results, and to modify such results with judgment based on experience.

The selection of suitable materials for the different parts ;—such as the best possible mixtures of cast iron for the cylinder, the use of phosphor bronze, good gun metal or even white metal in the bearings, and steel for all rods and spindles.

The form of those parts of which patterns have to be made is of importance ; and especially in cast iron or cast steel very great care must be used in the distribution of the metal, any sudden transition from thick to thin metal being a source of unsoundness in the castings, and in most cases the designer should endeavour to study the different parts to be made in cast metal from the moulder's side of the question, the best castings being almost invariably produced from patterns so formed as to leave the sand with ease, without rendering it necessary to "mend up" the mould ;—it being obvious that all mending up of a mould means a source of inaccuracy in the resulting casting, *i.e.* that it will differ from the pattern and no two castings will be obtained alike.

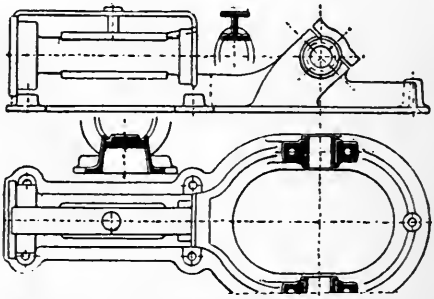
Good workmanship ;—the dearest is not always the best. Special attention should be given to the wearing surfaces, and in order to prevent hot bearings the brasses should always be bored out a fraction larger than the measured diameter of the shaft which runs in them ; it is often difficult to make a workman do this as he is apt to think that such a practice is against the idea of a "good fit ;" hot bearings often cost a factory considerable sums of money and may damage the reputation of an engine maker. Good lubrication is a necessity, and all oil holes in brasses or joints should be supplemented by distributing oil grooves or channels, deep enough to keep clear for a long time, a simple oil hole in a long bearing especially, is totally inadequate.

"An excessive or exaggerated seeking after improvements or originality is very objectionable, one holds to good and well tried

schemes. Every innovation should be discussed with a partner or a practical man, four eyes seeing more than two." The seeking after improvements or new appliances should always be encouraged, many useful schemes are lost by diffidence on the part of the schemer, which a little encouragement would allay.

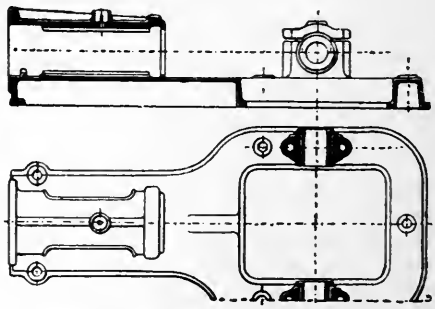
Besides one's own experience we may often make use of that of others, and notes of what we see, systematically arranged, so as to be easy to find, will afford much assistance.

## Frames for small Self-contained Horizontal Engines up to 15 inches stroke.

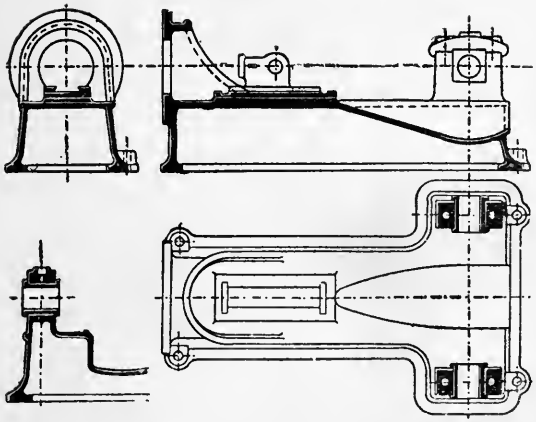


Figs. 41 and 42.—Frame, with double (top and bottom) slipper guides with flat surfaces.

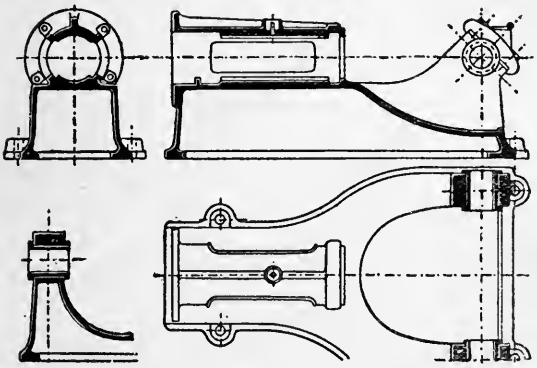
The crank shaft is bent or slotted out and admits of the flywheel being carried at either side of the engine outside the bearings, and if required a driving pulley at the opposite side. The crank shaft bearing brasses are generally in two pieces with a cap and two or four bolts.



Figs. 43 and 44.—Frame with bored Guides.

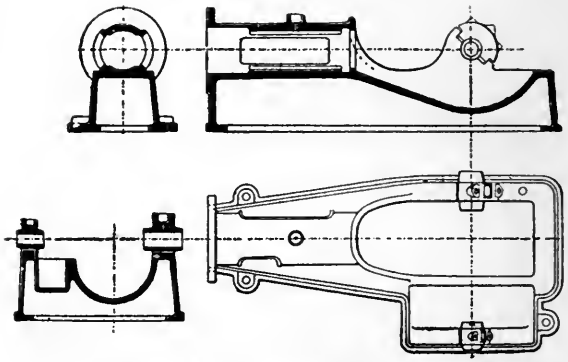


Figs. 45 and 46 – Frame with single slipper guide.



Figs. 47 and 48.—Frames with bored guides.

All the above frames are symmetrical about the centre line in plan



Figs. 49 and 50.—Frame with bored guides.

These frames are not symmetrical about the centre line and but little used, as right and left hand patterns would be required.

These engines can be used as wall engines by being bolted vertically with either the cylinder or crank shaft above; to a substantial wall; they are convenient also for transit as they can be packed complete with everything in its place except the fly-wheel.

The development of steam engine frames from earliest times to the present day is quite an interesting study, and has been progressing so quietly that it often escapes notice; formerly architectural features were always introduced, now smoothness of outline is almost universal, and the even disposition of metal is studied.

In horizontal engines of old types the bed was treated more or less as a plate whereon to bolt cylinders, guides and bearings; the metal was placed below, and far away from the centre line of the piston rod, so that the bed plate was subjected to a bending stress at each stroke of the piston, and these beds in some measure depended on the mass of masonry to which they were bolted for stiffness. In modern designing the tendency is to dispose the metal as nearly in the right place to resist stresses as possible. In girder engines the metal is disposed around the same horizontal plane as the piston rod, and as near to it as possible sideways; in vertical marine engines the frame is a stiff triangle, placed over the crank shaft; in marine paddle engines, &c., of diagonal type the metal is disposed in a most advantageous manner.

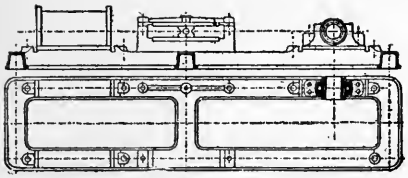


Fig. 51.

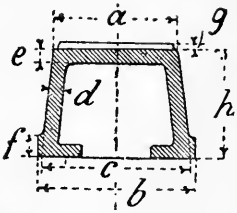



Fig. 52.

Bed-plate Frames of U-form section; an old type, but still used for large engines.

TABLE 1.—**Dimensions of the above Frames.**

| Engine. | | All Dimensions are in Inches. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| H* | D | *h* | *b* | *a* | *c* | *d* | *e* | *f* | *g* |
| 12 | 6 | $5\frac{1}{2}$ | 5 | $3\frac{1}{2}$ | 4 | $\frac{11}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{4}$ |
| 16 | 8 | 7 | 6 | $4\frac{1}{2}$ | 5 | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{4}$ |
| 24 | 12 | $8\frac{1}{2}$ | $7\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{3}{8}$ |
| 32 | 16 | $10\frac{1}{2}$ | 9 | 7 | 8 | $\frac{7}{8}$ | $\frac{7}{8}$ | 1 | $\frac{3}{8}$ |
| 40 | 20 | 12 | 10 | 9 | $9\frac{1}{2}$ | 1 | 1 | $1\frac{1}{8}$ | $\frac{1}{2}$ |
| 48 | 24 | 14 | 12 | $9\frac{1}{2}$ | 11 | $1\frac{1}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ |
| 56 | 28 | 16 | $13\frac{1}{2}$ | $10\frac{1}{2}$ | 12 | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ |
| 64 | 32 | 18 | 15 | $11\frac{1}{2}$ | 13 | $1\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{5}{8}$ |
| 72 | 36 | 20 | $16\frac{1}{2}$ | 13 | 15 | $1\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ |
| 80 | 40 | 22 | 18 | 14 | 16 | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $\frac{3}{4}$ |

* *Note.*—Throughout the Tables the letter H signifies the stroke of the engine, and D the diameter of the cylinder.

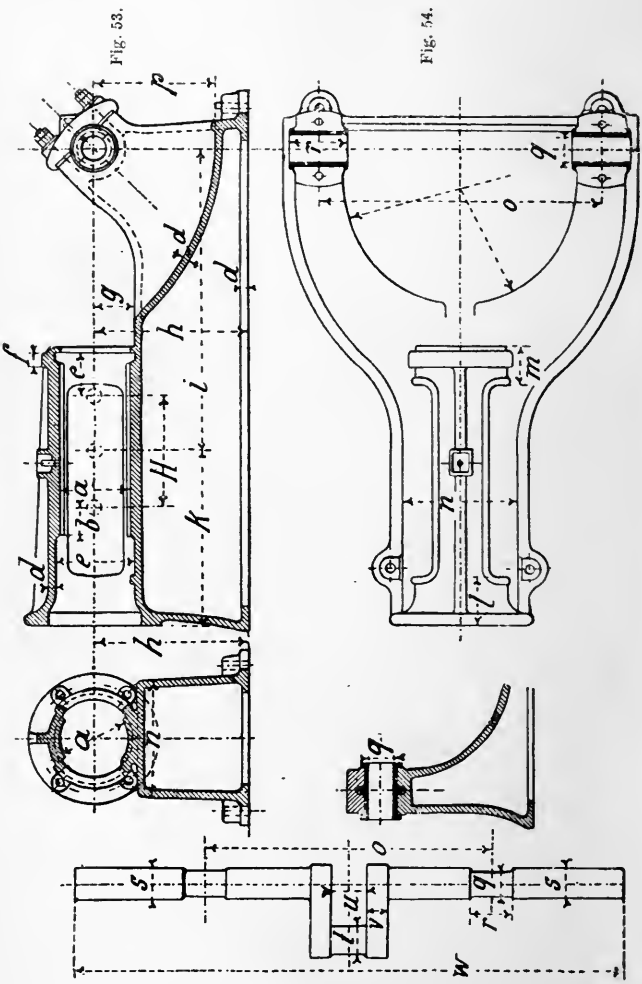


Fig. 53.
Fig. 54.
Fig. 55.

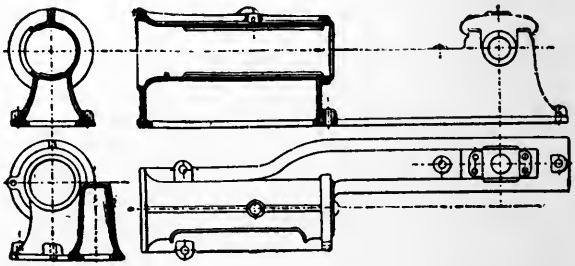
TABLE 2.—**Dimensions of Frames and Crank Shafts for small Engines** (Figs. 53—55).

| Engine. | | Frame | | | | | | | | | | | | | | | Main bearing. | | Crank Shaft. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* |
| 8 | 4 | 6 | 2 | $3\frac{1}{4}$ | $\frac{1}{2}$ | $6\frac{1}{2}$ | $1\frac{3}{8}$ | $3\frac{1}{2}$ | 12 | 22 | 14 | 4 | $3\frac{1}{2}$ | 10 | 22 | $9\frac{1}{2}$ | $2\frac{1}{2}$ | 5 | 3 | $2\frac{3}{4}$ | $3\frac{1}{4}$ | 2 | 48 |
| 12 | 6 | $7\frac{1}{2}$ | 3 | $4\frac{1}{4}$ | $\frac{5}{8}$ | $8\frac{1}{4}$ | $1\frac{5}{8}$ | $4\frac{1}{2}$ | 16 | 32 | 18 | $4\frac{3}{4}$ | 4 | 12 | 32 | $10\frac{1}{2}$ | 3 | 6 | $3\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{2}$ | $2\frac{3}{8}$ | 58 |

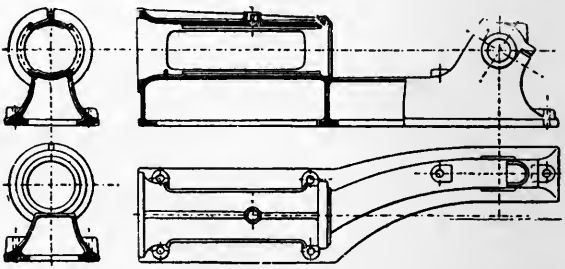
All Dimensions in this Table are given in Inches.

## Frames for Medium and Large Engines.

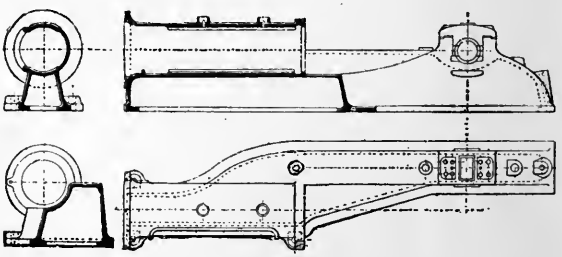
The bed plate frame as in page 19, fig. 51, was formerly largely used but now has given place to the more modern types given below; it has the advantage of taking firm hold of the foundation and is still much used for winding engines of large size.



Figs. 56 and 57.

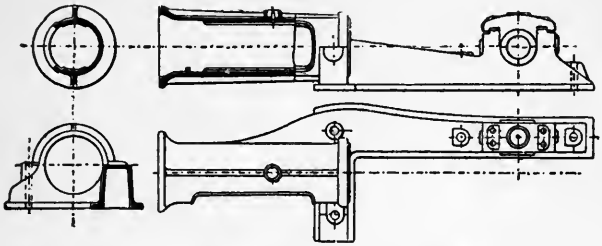


Figs. 58 and 59.

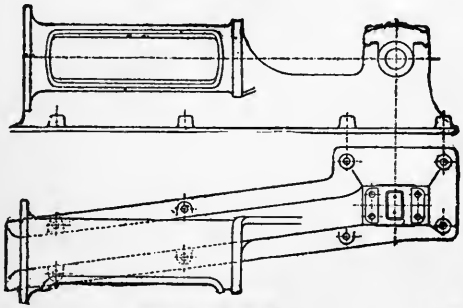


Figs. 60 and 61.

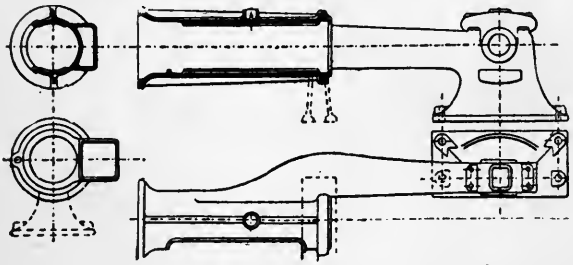
Figs. 61* & 62.



Figs. 63 & 64.



Figs. 65 & 66.



All the above frames Figs. 56—66 are of the semi-girder type having the frame supported throughout its length on the foundation except fig. 65, which is of the true girder type, the girder being free from the foundation, supports being at the ends, one under the cylinder the other at the main bearing. In the semi-girder type the cylinder usually overhangs the end of the frame.

*Note.*—The frame of a girder-winding engine at Herne, of 5′3″ stroke, cracked at (*a*), fig. 67, and the bending of the girder in the middle could be seen distinctly. A hole was drilled at the end of crack (*b*), and a supporting foot fixed under the girder at C.

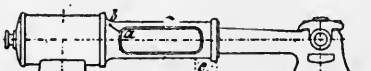
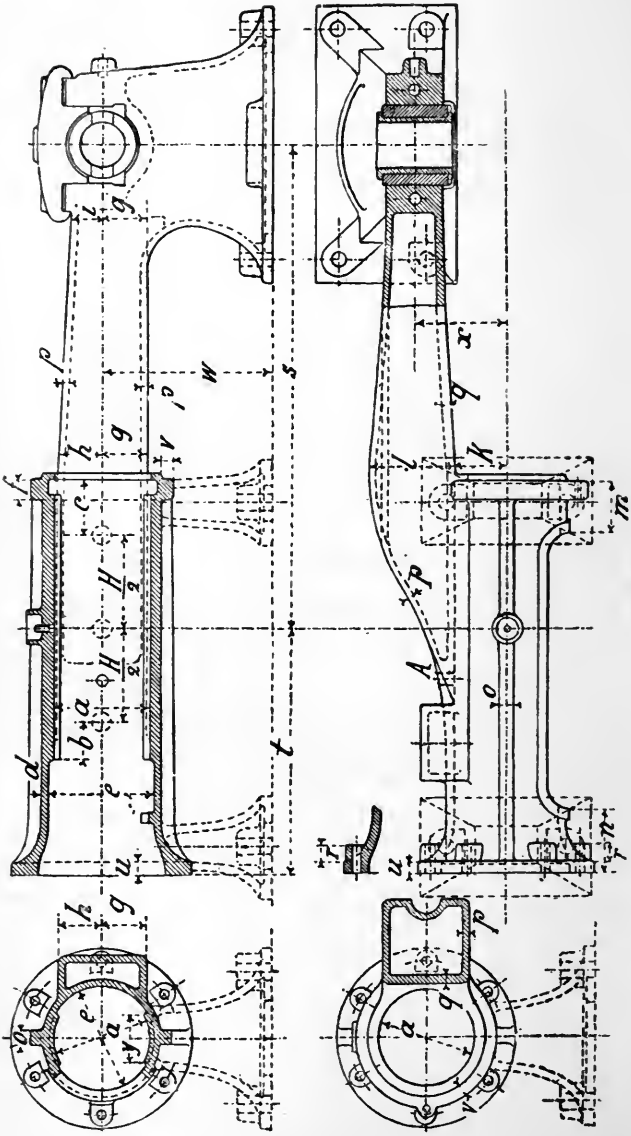


Fig. 67.



Figs. 68—70.

TABLE 3.—**Dimensions of Girder Frames with Bored Guides** (Figs. 68—70).

| Engine. | | All Dimensions are given in Inches. | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* | *x* | *y* |
| 20 | 10 | 11 | 4¼ | 5¾ | 11/16 | 11⅞ | 2¼ | 4¾ | 4½ | 2¾ | 5½ | 9 | 5½ | 6½ | 1⅜ | ¾ | ⅞ | 1¾ | 50 | 27 | 1⅜ | 1⅛ | 18 | 9¼ | 5 |
| 24 | 12 | 12 | 4¾ | 6½ | ¾ | 13 | 2⅜ | 5½ | 5 | 3¼ | 6½ | 10 | 6½ | 7½ | 1½ | ¾ | 1 | 2 | 60 | 30¾ | 1½ | 1⅜ | 20 | 10¾ | 6¼ |
| 28 | 14 | 13½ | 5½ | 7¼ | 13/16 | 14⅝ | 2½ | 6¼ | 6 | 3¾ | 7½ | 11½ | 7 | 8 | 1¾ | ⅞ | 1 | 2¼ | 70 | 34 | 1½ | 1½ | 22 | 12¼ | 7¼ |
| 32 | 16 | 15 | 6 | 8 | ⅞ | 16½ | 2¾ | 7¼ | 6¾ | 4½ | 8¼ | 13 | 8 | 9 | 2 | ⅞ | 1⅛ | 2½ | 80 | 37½ | 1⅝ | 1¾ | 24 | 14 | 8 |
| 36 | 18 | 17 | 6¼ | 8¾ | ⅞ | 18½ | 3 | 8 | 7½ | 5 | 9½ | 14½ | 8½ | 9½ | 2¼ | ⅞ | 1⅛ | 2⅞ | 90 | 41 | 1¾ | 2 | 26 | 15⅝ | 8¾ |
| 40 | 20 | 19 | 6¾ | 9½ | 15/16 | 20½ | 3¼ | 8¾ | 8 | 5½ | 10½ | 15½ | 9½ | 10½ | 2½ | 1 | 1¼ | 3¼ | 100 | 44¼ | 2 | 2¼ | 28 | 17¼ | 9½ |
| 44 | 22 | 21 | 7 | 10 | 1 | 22½ | 3½ | 9½ | 8¾ | 6 | 11½ | 16½ | 10 | 11 | 2¾ | 1 | 1¼ | 3½ | 110 | 48¾ | 2¼ | 2½ | 30 | 18½ | 10 |

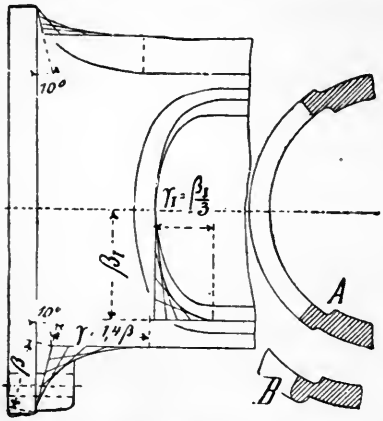
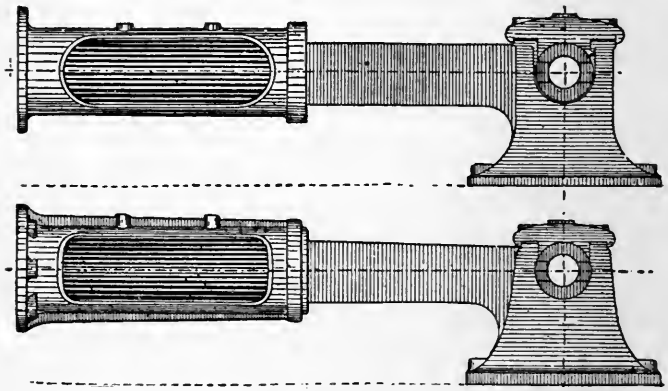



Fig 71

The opening or window for the crosshead has ends in the form of a parabola with axes as 1 to 3 and a fillet is carried round the window either as at A or B. Fig. 71 also shows the blending of the round part of the frame with the flange to which the cylinder is bolted; the guides are sometimes finished as shown in Figs. 72, 73.



Figs. 72 and 73.

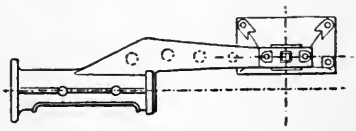


Fig. 74.

Fig. 74 shows the connection between the part of the frame with the bored out guides and the main crank-shaft-bearing, the straight line forms shown in the figure, makes the pattern simple; the dotted circles show the holes for venting the core and for getting it out of the casting.

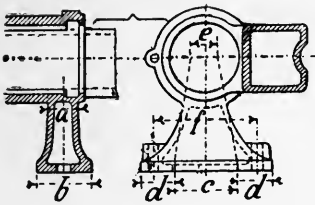



Fig. 75.

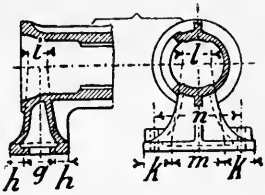



Fig. 76.

TABLE 4.—**Feet for supporting Girder Frames** (Figs. 75—77).

| Engines. | | Feet supporting middle of Girder. | | | | | | Feet at Cylinder end of Girder. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* |
| 20 | 10 | — | — | — | — | — | — | 6 | $2\frac{1}{2}$ | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $4\frac{3}{4}$ | 8 | 15 |
| 24 | 12 | — | — | — | — | — | — | $6\frac{3}{4}$ | $2\frac{1}{2}$ | 5 | $6\frac{1}{4}$ | $5\frac{3}{4}$ | $9\frac{1}{2}$ | 17 |
| 28 | 14 | — | — | — | — | — | — | $7\frac{1}{2}$ | $2\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{3}{4}$ | $6\frac{3}{4}$ | $11\frac{1}{2}$ | $19\frac{1}{2}$ |
| 32 | 16 | $5\frac{1}{2}$ | 10 | 12 | $7\frac{1}{4}$ | $6\frac{1}{2}$ | 21 | — | — | — | — | — | — | — |
| 36 | 18 | $6\frac{3}{4}$ | $10\frac{1}{2}$ | $12\frac{3}{4}$ | $7\frac{1}{2}$ | $6\frac{3}{4}$ | 22 | — | — | — | — | — | — | — |
| 40 | 20 | $7\frac{1}{4}$ | 11 | $13\frac{1}{2}$ | 8 | $7\frac{1}{4}$ | 23 | — | — | — | — | — | — | — |
| 44 | 22 | $7\frac{1}{2}$ | $11\frac{1}{2}$ | $14\frac{1}{2}$ | $8\frac{3}{4}$ | $7\frac{1}{2}$ | $25\frac{1}{2}$ | — | — | — | — | — | — | — |

All Dimensions are in Inches.

Small engines up to 12″ diameter of cylinder are frequently made with overhanging cylinders and with the foot cast in one with the girder as shown in fig. 76.

For larger engines an intermediate supporting foot is sometimes cast or bolted on to the girder. The curve of the sides of these feet is parabolic, fig. 77

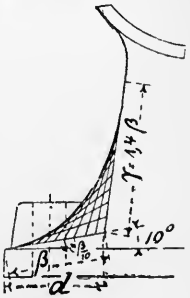



Fig. 77.

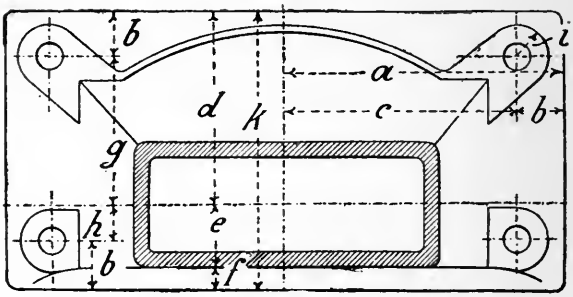



Fig. 78.*

TABLE 5.—**Main Bearing Foot** (Fig. 78).

| Engines. | | All Dimensions are in Inches. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* |
| 20 | 10 | $13\frac{1}{4}$ | 2 | $11\frac{1}{4}$ | 9 | $2\frac{7}{8}$ | $1\frac{1}{8}$ | 7 | 2 | $1\frac{3}{4}$ | 13 |
| 24 | 12 | $14\frac{3}{4}$ | $2\frac{1}{2}$ | $12\frac{1}{4}$ | 11 | $3\frac{3}{8}$ | $1\frac{5}{8}$ | $8\frac{1}{2}$ | $2\frac{1}{2}$ | 2 | 16 |
| 28 | 14 | 18 | $2\frac{1}{2}$ | $15\frac{1}{2}$ | 12 | $3\frac{7}{8}$ | $2\frac{1}{8}$ | $9\frac{1}{2}$ | $3\frac{1}{2}$ | $2\frac{1}{4}$ | 18 |
| 32 | 16 | 20 | $2\frac{3}{4}$ | $17\frac{1}{4}$ | 13 | $4\frac{3}{8}$ | $2\frac{1}{8}$ | $10\frac{1}{4}$ | $3\frac{3}{4}$ | $2\frac{1}{4}$ | $19\frac{1}{2}$ |
| 36 | 18 | $21\frac{1}{2}$ | $2\frac{3}{4}$ | $18\frac{3}{4}$ | 15 | $4\frac{7}{8}$ | $1\frac{5}{8}$ | $12\frac{1}{4}$ | $3\frac{3}{4}$ | $2\frac{1}{2}$ | $21\frac{1}{2}$ |
| 40 | 20 | 24 | $3\frac{1}{4}$ | $21\frac{3}{4}$ | 16 | $5\frac{3}{8}$ | $2\frac{1}{8}$ | $12\frac{3}{4}$ | $4\frac{1}{4}$ | $2\frac{1}{2}$ | $23\frac{1}{2}$ |
| 44 | 22 | 26 | $3\frac{1}{4}$ | $22\frac{3}{4}$ | 18 | 6 | $2\frac{1}{2}$ | $14\frac{3}{4}$ | $5\frac{1}{4}$ | $2\frac{3}{4}$ | $26\frac{1}{2}$ |

* This foot is not symmetrical about the longitudinal centre line, and therefore cannot be used for both right and left-hand engines without alteration to patterns unless bolted to girders by a flange.

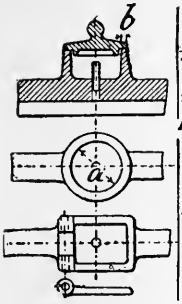



Fig. 79.

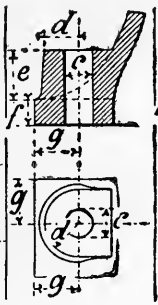



Fig. 80.

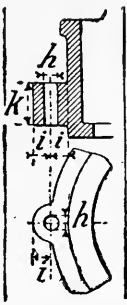



Fig 81.

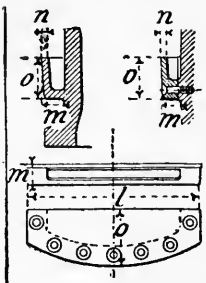



Fig. 82.

TABLE 6.—**Sundry Details for Girder Frames** (Figs. 79—82).

| H | Oil Cup for Guides. | | | Bosses for Foundation Bolts | | | | | Boss for Guard Rail. | | | Oil Catcher for Main Bearing. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* |
| 8 | 1 | 1½ | ¼ | 1⅛ | 1¼ | 1⅜ | 1 | 1½ | — | — | — | — | — | — | — |
| 12 | 1 | 2 | ¼ | 1¼ | 1⅜ | 1½ | 1¼ | 1¾ | — | — | — | — | — | — | — |
| 16 | 1 | 2½ | ¼ | 1⅜ | 1½ | 1¾ | 1⅜ | 2 | ⅝ | ¾ | 2 | 9 | 1 | ¼ | 2 |
| 20 | 1 | 2¾ | ⅜ | 1½ | 1¾ | 2 | 1½ | 2¼ | ¾ | ⅞ | 2¼ | 10 | 1 | ¼ | 2 |
| 24 | 1 | 3¼ | ⅜ | 1¾ | 2 | 2 | 1¾ | 2½ | ¾ | 1 | 2⅜ | 11 | 1⅛ | ¼ | 2⅜ |
| 28 | 1 | 3¾ | ⅜ | 2 | 2¼ | 2⅜ | 2 | 2¾ | ⅞ | 1 | 2½ | 12 | 1⅛ | ¼ | 2½ |
| 32 | 2 | 3¼ | ⅜ | 2⅛ | 2¼ | 2½ | 2¼ | 3 | 1 | 1 | 2¾ | 13 | 1¼ | ⅜ | 2¾ |
| 36 | 2 | 3½ | ½ | 2¼ | 2½ | 2¾ | 2⅜ | 3¼ | 1 | 1⅛ | 3 | 14 | 1¼ | ⅜ | 3 |
| 40 | 2 | 3¾ | ½ | 2¼ | 2½ | 3 | 2½ | 3¼ | 1 | 1¼ | 3¼ | 15 | 1⅜ | ⅜ | 3¼ |
| 44 | 2 | 4 | ½ | 2⅜ | 2¾ | 3¼ | 2⅝ | 3½ | 1⅛ | 1⅜ | 3½ | 16 | 1½ | ½ | 3½ |

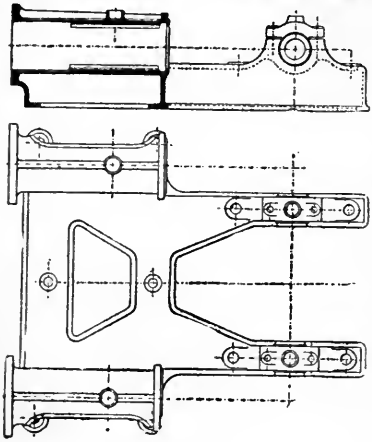
All Dimensions are in Inches.

Figs. 83—86.

TABLE 7.—**Dimensions of Frames with bored Guides supported on Foundation from end to end, "semi-girder" type** (Figs. 83—86).

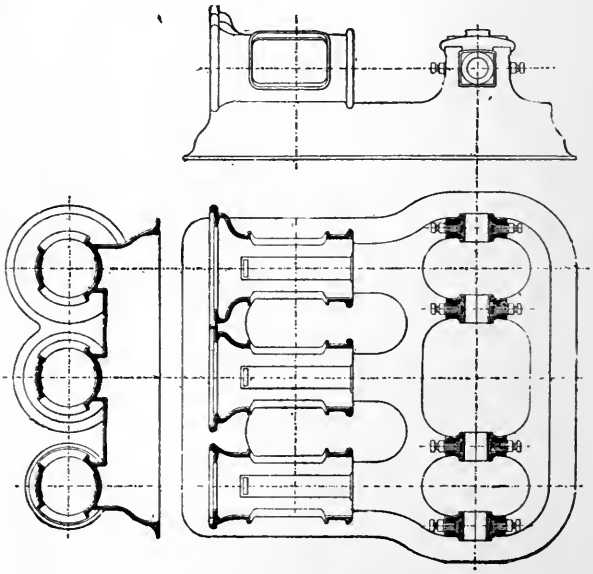
| Engine. | | All Dimensions are in Inches. | | | | | | | | | | | | | | | | | No. of Bolts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | |
| 16 | 8 | 9 | 10 | $\frac{5}{8}$ | 42 | $12\frac{3}{4}$ | $8\frac{3}{4}$ | 14 | $5\frac{1}{2}$ | 5 | $4\frac{1}{2}$ | $5\frac{3}{4}$ | $7\frac{1}{4}$ | $9\frac{1}{4}$ | 28 | $\frac{3}{4}$ | $\frac{3}{4}$ | $17\frac{1}{4}$ | 7 |
| 20 | 12 | 12 | 13 | $\frac{3}{4}$ | 62 | $19\frac{1}{4}$ | 12 | 19 | $7\frac{1}{2}$ | $6\frac{1}{2}$ | $6\frac{1}{4}$ | 8 | $8\frac{3}{4}$ | $12\frac{3}{8}$ | 38 | $\frac{3}{4}$ | 1 | $19\frac{1}{2}$ | 7 |
| 32 | 16 | 15 | $16\frac{1}{2}$ | $\frac{3}{4}$ | 80 | $24\frac{3}{4}$ | $15\frac{1}{4}$ | 24 | $8\frac{3}{4}$ | $7\frac{1}{2}$ | 8 | $9\frac{1}{2}$ | $10\frac{1}{2}$ | $15\frac{1}{4}$ | 48 | $\frac{7}{8}$ | $1\frac{1}{4}$ | 22 | 8 |
| 40 | 20 | 19 | $20\frac{1}{2}$ | $\frac{7}{8}$ | 100 | $30\frac{1}{2}$ | $17\frac{1}{2}$ | 28 | $10\frac{1}{2}$ | $8\frac{1}{2}$ | $9\frac{1}{2}$ | 12 | 12 | $19\frac{1}{4}$ | 56 | 1 | $1\frac{3}{8}$ | 25 | 8 |
| 48 | 24 | 23 | $24\frac{1}{2}$ | 1 | 120 | 36 | $20\frac{1}{2}$ | 32 | $11\frac{1}{2}$ | $9\frac{1}{4}$ | $11\frac{1}{4}$ | $15\frac{1}{4}$ | $13\frac{1}{2}$ | $23\frac{5}{8}$ | 67 | $1\frac{1}{8}$ | $1\frac{1}{2}$ | 28 | 9 |
| 56 | 28 | 27 | $28\frac{1}{2}$ | $1\frac{1}{8}$ | 140 | 42 | $27\frac{1}{4}$ | 36 | $12\frac{1}{2}$ | 10 | $12\frac{3}{4}$ | $17\frac{3}{4}$ | $15\frac{1}{4}$ | $27\frac{1}{4}$ | 72 | $1\frac{1}{4}$ | 2 | 31 | 10 |
| 64 | 32 | 31 | $32\frac{1}{2}$ | $1\frac{1}{4}$ | 160 | 48 | 30 | 40 | $13\frac{1}{2}$ | 11 | $14\frac{1}{2}$ | 20 | $16\frac{3}{4}$ | $30\frac{3}{4}$ | 80 | $1\frac{1}{4}$ | $2\frac{1}{2}$ | 34 | 11 |
| 72 | 36 | $34\frac{1}{2}$ | 36 | $1\frac{3}{8}$ | 176 | 54 | $32\frac{3}{4}$ | 42 | $14\frac{1}{2}$ | $11\frac{3}{4}$ | $17\frac{1}{4}$ | 22 | $18\frac{1}{2}$ | $33\frac{5}{8}$ | 84 | $1\frac{3}{8}$ | $2\frac{3}{4}$ | 37 | 12 |
| 80 | 40 | $38\frac{1}{2}$ | 40 | $1\frac{3}{8}$ | 192 | 60 | 36 | 44 | $15\frac{1}{4}$ | $12\frac{3}{4}$ | 20 | $24\frac{3}{4}$ | 20 | $37\frac{5}{8}$ | 88 | $1\frac{3}{8}$ | $3\frac{1}{4}$ | 40 | 12 |

## Frames for Horizontal Engines with more than One Cylinder.



Figs. 87 and 88.

Figs. 87, 88 show a frame for a double cylinder engine with fly-wheel between the two cylinders. A very convenient and cheap type for small self-contained engines. The size of the fly-wheel is limited in this arrangement to about three and a half times the crank radius.



Figs. 89—91.

Figs. 89—91 show a frame for a triple expansion horizontal engine of 20 inches stroke, the arrangement for adjusting the crank shaft brasses by set screws is not recommended, although formerly it was a very common practice.*

## Frames for Vertical Engines.

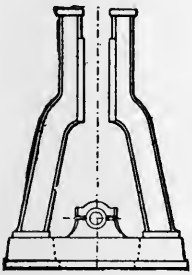


Fig 92.

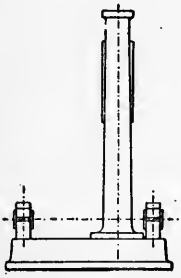


Fig. 93.

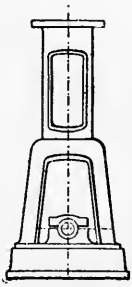


Fig. 94.

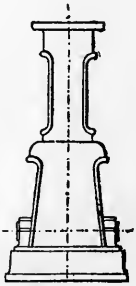


Fig. 95.

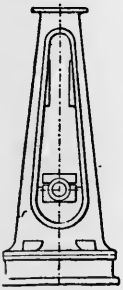


Fig. 96

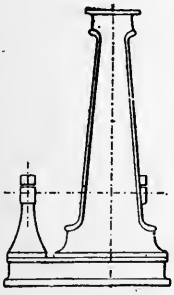


Fig. 97

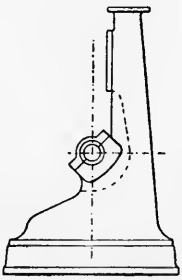


Fig 98

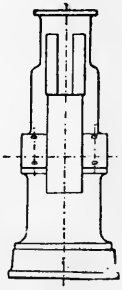
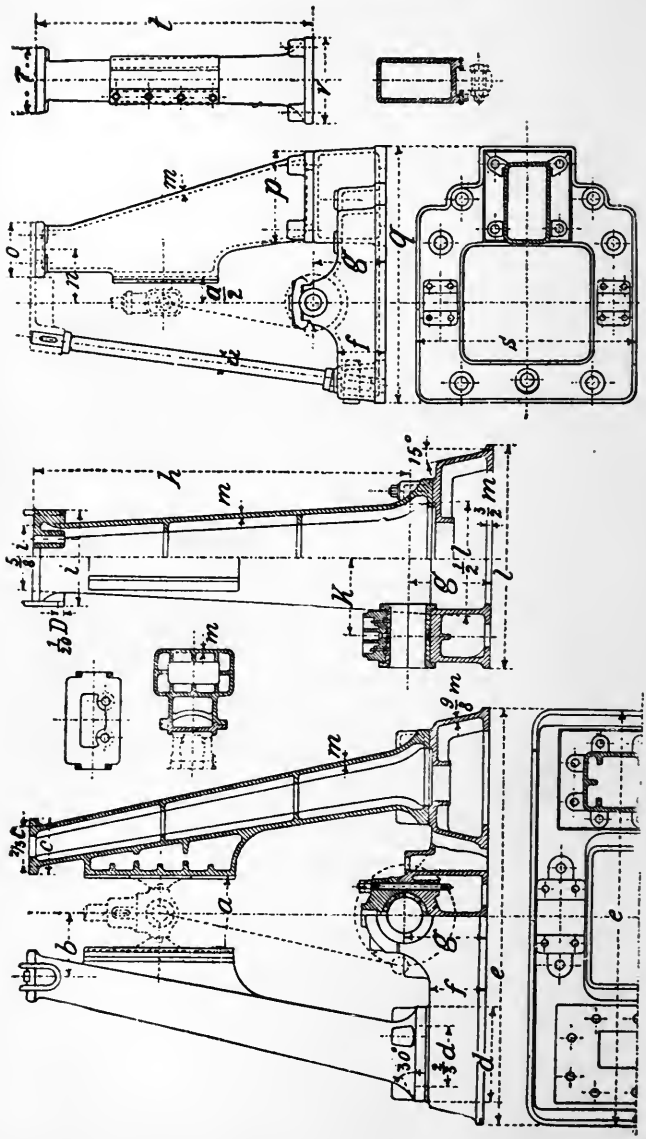


Fig. 99.

The above figs. 92—99 show some early types of vertical engine frames for small engines, a modification of fig. 98 is now used for small quick running engines, and has a wrought-iron stay bar brought from a lug on the cylinder down to the front of the base of the frame.

* See "Zeitschrift der Verein deutsch. Ingenieur, 1888," page 226.



Figs. 100—102.



Figs. 103—105.

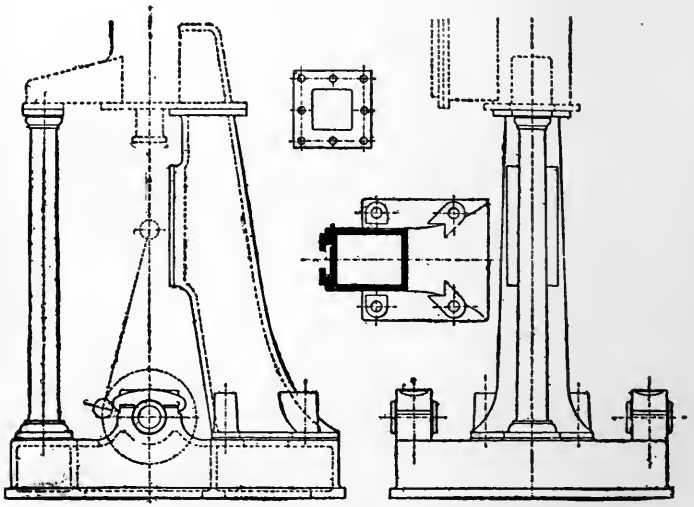
TABLE 8.—**Dimensions of Frames for Vertical Engines** (Figs. 100—105).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 6 | 11 | — | — | — | — | 11 | 18 | — | — | — | — | $\frac{5}{8}$ | 11 | 11 | 18 | 48 | 12 | 48 | 42 | | 16 | |
| 12 | 10 | 13 | — | — | — | — | 12 | 19 | — | — | — | — | $\frac{11}{16}$ | 13 | 13 | 21 | 60 | 15 | 57 | 60 | | 2 | |
| 16 | 14 | 15 | — | — | — | — | 13 | 20 | — | — | — | — | $\frac{3}{4}$ | 15 | 15 | 25 | 72 | 18 | 66 | 78 | | 24 | |
| 20 | 18 | 17 | — | — | — | — | 14 | 21 | — | — | — | — | $\frac{5}{8}$ | 17 | 17 | 29 | 84 | 21 | 75 | 96 | | 28 | |
| 24 | 22 | 19 | — | — | — | — | 15 | 22 | — | — | — | — | $\frac{7}{8}$ | 19 | 19 | 32 | 96 | 24 | 84 | 114 | | 32 | |
| 28 | 26 | 21 | 17 | 15 | $26\frac{1}{2}$ | 120 | 16 | 23 | 108 | $26\frac{1}{2}$ | 22 | 64 | $\frac{15}{16}$ | — | — | — | — | — | — | — | — | — | — |
| 32 | 30 | 23 | $18\frac{1}{2}$ | 16 | 29 | 132 | $17\frac{1}{2}$ | 25 | 120 | 29 | 24 | 70 | 1 | — | — | — | — | — | — | — | — | — | — |
| 36 | 34 | 25 | 20 | $17\frac{1}{2}$ | $31\frac{1}{2}$ | 144 | 19 | 27 | 132 | $31\frac{1}{2}$ | 26 | 76 | $1\frac{1}{16}$ | — | — | — | — | — | — | — | — | — | — |
| 40 | 38 | 27 | $21\frac{1}{2}$ | 19 | 34 | 156 | $20\frac{1}{2}$ | 29 | 144 | 34 | 28 | 82 | $1\frac{1}{8}$ | — | — | — | — | — | — | — | — | — | — |
| 44 | 44 | 29 | 23 | $20\frac{1}{2}$ | 36 | 168 | 22 | 31 | 156 | $36\frac{1}{2}$ | 30 | 88 | $1\frac{3}{16}$ | — | — | — | — | — | — | — | — | — | — |

All Dimensions are given in Inches.

Figs. 100—102 show a vertical engine frame of cast iron for large engines of the marine type, the outer bearing is here on a separate bed outside the fly-wheel when used as a land engine.

Figs. 103—105 show a vertical engine frame of cast iron with wrought-iron stay bar in front, and both crank shaft bearings on one bed thus making the engine self-contained.



Figs. 106—109.

Figs. 106—109 show a frame of the marine type modified for self-contained vertical land engines.

## Crank Shaft Bearings.

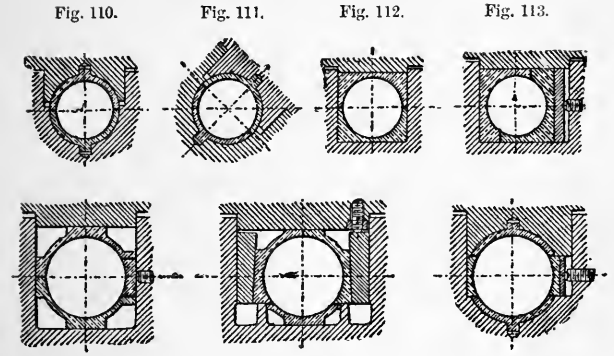


Fig. 110. Fig. 111. Fig. 112. Fig. 113.

Fig. 114. Fig. 115. Fig. 116.

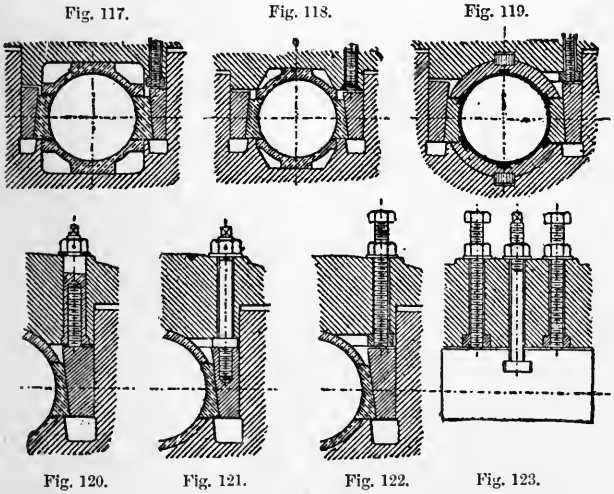
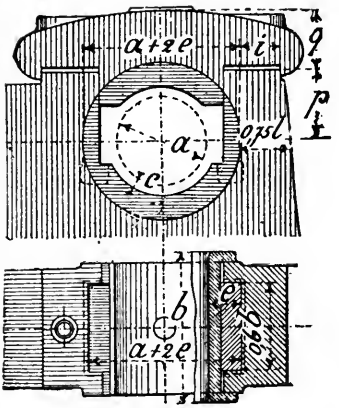


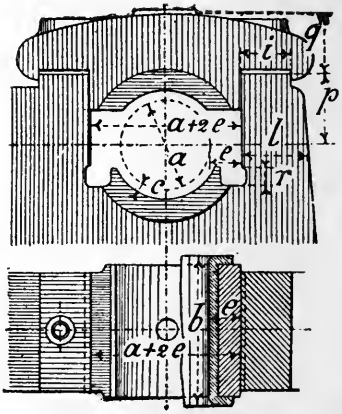
Fig. 117. Fig. 118. Fig. 119.

Fig. 120. Fig. 121. Fig. 122. Fig. 123.

Figs. 110–113.—Bearings with brasses in two parts for small engines.
Figs. 114–116.—Bearings with brasses in three parts for medium-sized engines.
Figs. 117–123.—Bearings with brasses in four parts for large engines.




Figs. 124 and 125.




Figs. 126 and 127.

Figs. 124—127 show two different designs of bearings ; in one, Fig. 124, the adjusting wedge is difficult to fit in, and in fig. 126, if desirable to cover up the wedge at the sides, the flanges of the brasses require to be very deep.

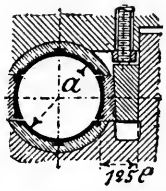
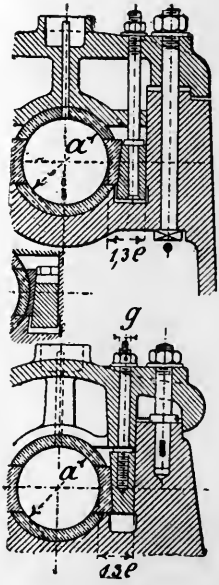



Fig. 128.

Fig. 128 shows the bearings of cast iron or cast steel lined with white metal. In large bearings the caps are often cored out to lighten them, as shown in section in figs. 129—131 ; these figures also show two methods of adjusting the brasses endways or horizontally. The outline of the bearing foot is made approximately parabolic, a curve which gives perhaps the neatest appearance.

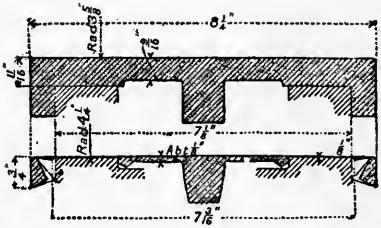



Figs. 129—131.

It will be noted in fig. 128 that the adjusting wedge is shown with the *small end* downwards ; it is generally better to have all adjusting wedges with the *large end* downwards, as then, if the bolt jars loose, the wedge will work down, and not jamb as it might do when put in the other way.

The crank shaft or main bearing, being a very important part of the engine, requires special care both in design and construction. The adjustment of bearings with the brasses in three or more parts by means of wedges placed so as to take up the wear in definite directions, has many advantages if skilfully handled, but may lead to bad results and prove to be far worse, than the ordinary bearing with two-part brasses, if badly handled. On this ground, many firms make even large engines with two-part brasses and no wedge adjustment. It is noticeable that both in marine and locomotive practice the bearings are made as simple as possible without any elaborations.

The part of the brass step which rests on the body casting of the bearing should always be well fitted and have ample surface. Figs. 132, 133, show the section of a crank shaft brass when new and after many years wear, the lower fig. shows how the material of the brass spreads out in the direction of its length by the continual pressure and jarring of ordinary work.*



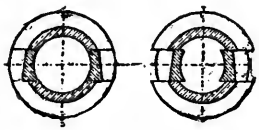
Figs. 132 and 133.

Crank shaft and other similar brasses have a tendency to close in and pinch the shaft as they become warm, to avoid this trouble two-part brasses should be bored out 0·5 per cent. and four-part brasses 0·8 per cent. larger than the diameter of the shaft, attention to this point would often save trouble in ordinary shafting, the brasses of which are often sent out a tight fit on the shaft and have generally to be filed or scraped out until they are a comparatively loose fit.

To bore out and fit up brasses, especially when in many pieces, they are planed up on the flat joint surfaces and soldered together, and can then be bored out, turned or machined where required, and fitted to their places, and afterwards readily separated by heat; sometimes, where possible, they are held together by clamps and steady pins.

* Zeitschrift der Verein deutsches Ingenieur, 1890, page 931.

A suitable mixture for white metal is, according to Kirchweger, composed of 9½ parts copper, 13 parts antimony, 59 parts of pure zinc : the copper should be first melted, then the antimony and zinc added and the mixture well stirred and granulated ; 27 parts of this granulated metal should then be melted, and 29½ parts of pure zinc added, the mixture well stirred and run into bars. There are numbers of different metals now used for lining engine and other bearings, one of the first used was Babbit's metal, said to be composed of 1 part copper, 10 parts tin, and 1 part antimony. All these alloys of metals, differing much in their melting points, should be mixed with care, otherwise the easily fusible metals will volatilize, and unsatisfactory results will be obtained. Other standard metals used for engine brasses vary in their composition according to the judgment and experience of the manufacturer, they usually are composed of copper, tin and zinc, copper and tin being the chief ingredients.



Figs. 134 and 135.

The heating of bearings may proceed from the construction, maintenance or attention, or rather want of attention, whilst at work, and even when at rest.

The causes of heating may be tabulated as follows:—

1. Too high pressure per unit of surface P.
2. Too great speed of the shaft for the given pressure, *i.e.*, $p\ v$ too great.
3. Too much pressure from the shaft being not sufficiently stiff for the work, *i.e.*, shaft too elastic.
4. Unsuitable material for the brasses or steps.
5. Insufficient means of lubrication.
6. Blows or jars.

Then let $d$ = diameter of journal in inches.
$l$ = length of journal in inches.
$n$ = speed in revolutions per minute.
P = total pressure in lbs.
$p$ = pressure per square inch in lbs.
$v$ = periphery speed of the journal in feet per second,

then, for ordinary engines :

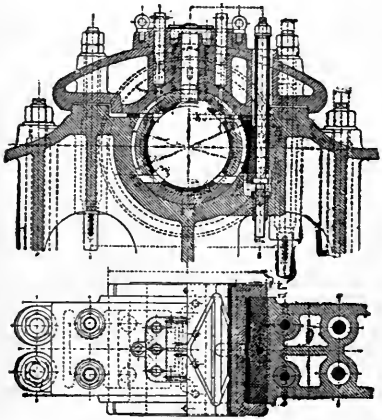
$$p \leqq 270\ ;\ p\ v \leqq 840.$$

These figures do not give the limit to which the pressure and speed may be carried, the table gives some examples taken from engines which have been running for some years.

TABLE 9.—**Examples of Main Bearings from Actual Practice.**

| Diam. of Steam Cyl. in. | Stroke. in. | Revolution per min. | *d.* in. | *l.* in. | P. lbs. | *p.* lbs. per sq. in. | *p. v.* foot-lbs. p. sec. & sq. in. | Material of Bearings. | Machinery driven by engine. |
|---|---|---|---|---|---|---|---|---|---|
| 17·7 | 27·5 | 66 | 6·7 | 10·8 | 28200 | 381 | 750 | Babbited Gun metal | Electric light |
| 23·6 | 43·3 | 75 | 12·6 | 24·4 | 37500 | 122 | 503 | Gun metal | Roller mills |
| 23·6<br>35·4 | 41·3 | 60 | 8·6 | 14·2 | 46100 | 378 | 851 | Babbit | Flour mill |
| 23·6<br>39·3 | 39·4 | 120 | 9·8 | 14·5 | 30800 | 277 | 1113 | Gun metal | Roller mills |
| 25·6 | 25·6 | 150<br>180 | 9·6 | 15·7 | 34800 | 235 | 1477<br>1772 | Babbit | Roller mills |
| 27·5 | 39·4 | 100 | 10·2 | 16·5 | 49500 | 290 | 1549 | Babbit | Roller mills |
| 31·5 | 47·2 | 80 | 12·2 | 19·7 | 52300 | 217 | 924 | Gun metal | Roller mills |
| 35·4 | 53·1 | 80 | 14·2 | 22·8 | 78200 | 242 | 1095 | Gun metal | Roller mills |
| 49·2 | 49·2 | 80<br>90 | 17·1 | 23·6 | 156200 | 387 | 2310<br>2599 | Babbit | Roller mills |

**The Lubrication of Bearings** is of great importance, and efficient means should always be provided for supply and distribution of the oil or other lubricant. Figs. 136, 137, give a section through the crank-shaft bearing of an engine used for driving a rolling mill. The lubricant is a stiff grease, and is delivered into the bearing by six pistons of gas tube, shown in the fig. 136 in their respective holes in the cap; from these the grease is forced by the weight of the pistons into channels formed at the joints of the different parts of the brass. The engine from which this example is taken has a cylinder of 39 ins. diameter, and the stroke is 55 ins.



Figs. 136 and 137.

The large opening in the centre of the cap can be filled up with lard (*speck*), a material largely used in rolling mills. The adjusting wedge is of the same form as that shown in fig. 127.

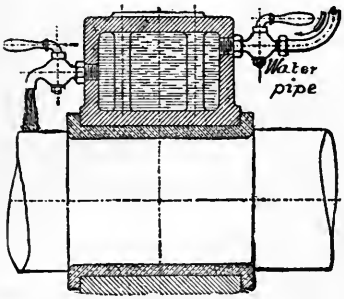



Fig. 138.

Water is occasionally used to cool down hot bearings, applied as shown in fig. 138; with marine engines water is laid on to most of the bearings through small copper pipes from a cistern, each pipe being provided with a tap. Figs. 139—142 give examples of a large crank shaft bearing, with the dimensions given in inches in Table 10 below.

Solidified oil or grease has been successfully introduced for the lubrication of engine and other bearings; it is forced into the oil grooves by a special screw cap to the lubricator, such as those of Stauffer and others.

Fig. 139. Fig. 141.

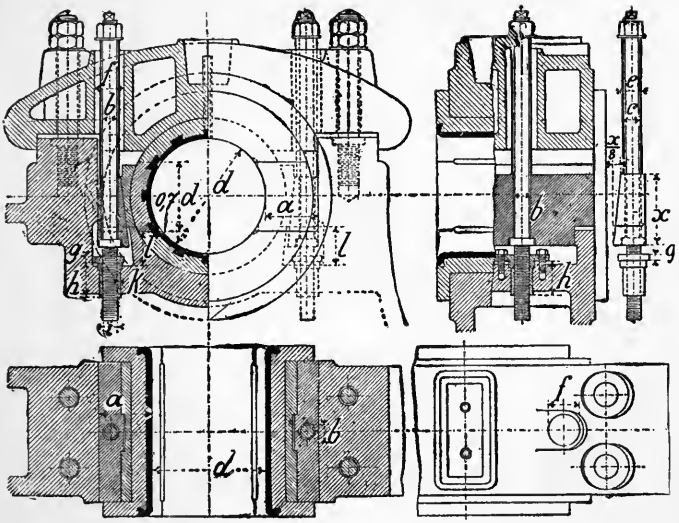
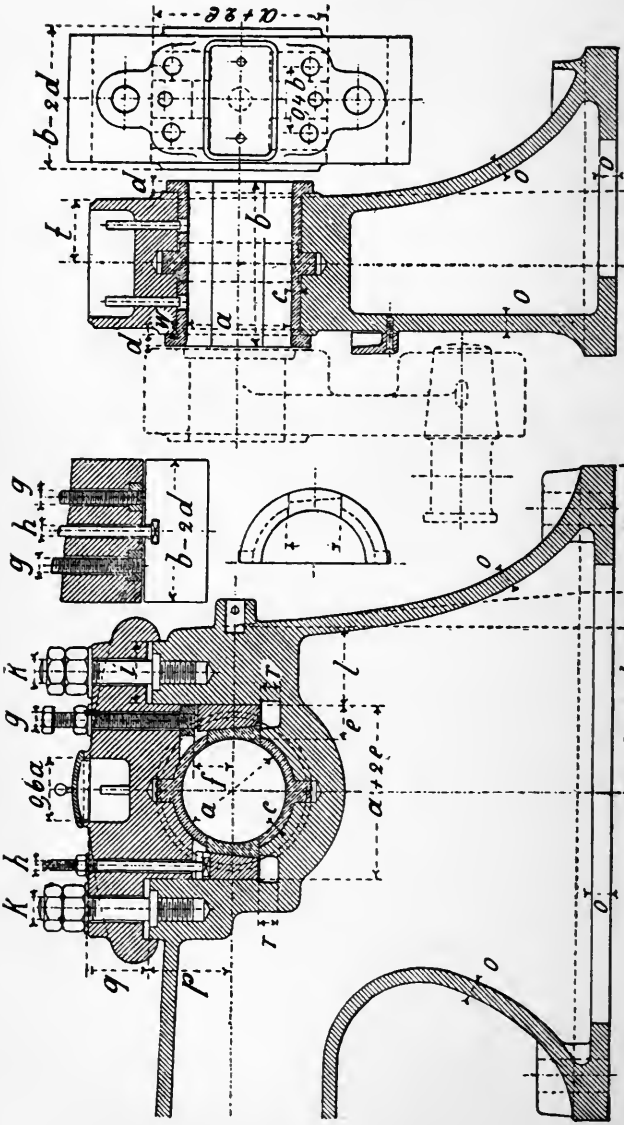



Fig. 140. Fig. 142.

Figs. 139—142.—Bearing with Brasses in Four Parts.

TABLE 10.—**Dimensions of Bearings** (Figs. 139—142).

| $d$ | $a$ | $b$ | $c$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7 | $3\frac{5}{8}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $2\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $2\frac{1}{2}$ |
| $7\frac{1}{2}$ | $3\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{1}{4}$ | 1 | $\frac{1}{4}$ | $2\frac{1}{2}$ |
| 8 | 4 | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{3}{8}$ | 1 | $\frac{1}{4}$ | $2\frac{3}{4}$ |
| $8\frac{1}{2}$ | $4\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{5}{16}$ | 3 |
| 9 | $4\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{1}{2}$ | $2\frac{3}{4}$ | $1\frac{1}{8}$ | $\frac{5}{16}$ | $3\frac{1}{8}$ |
| 10 | $4\frac{7}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $3\frac{1}{8}$ | $\frac{1}{2}$ | 3 | $1\frac{1}{4}$ | $\frac{3}{8}$ | $3\frac{1}{4}$ |
| 11 | $5\frac{3}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $2\frac{3}{8}$ | $3\frac{1}{8}$ | $\frac{1}{2}$ | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{3}{8}$ | $3\frac{1}{2}$ |
| 12 | $5\frac{3}{4}$ | $1\frac{3}{8}$ | 2 | $2\frac{3}{8}$ | $3\frac{1}{2}$ | $\frac{1}{2}$ | $3\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{7}{16}$ | $3\frac{3}{4}$ |
| 13 | $6\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $2\frac{3}{8}$ | $3\frac{3}{4}$ | $\frac{5}{8}$ | $3\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | 4 |
| 14 | $6\frac{1}{2}$ | $1\frac{1}{2}$ | 2 | 3 | $3\frac{3}{4}$ | $\frac{5}{8}$ | 4 | $1\frac{1}{2}$ | $\frac{1}{2}$ | $4\frac{1}{4}$ |
| 15 | 7 | $1\frac{3}{4}$ | $2\frac{1}{2}$ | 3 | $4\frac{3}{8}$ | $\frac{5}{8}$ | $4\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $4\frac{1}{2}$ |
| 16 | $7\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{2}$ | 3 | $4\frac{3}{8}$ | $\frac{5}{8}$ | $4\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $4\frac{3}{4}$ |



Figs. 144 and 145.

Fig. 143.

TABLE 11.—**Dimensions of Crank Shaft Bearings** (Figs. 143—145).

| Engine. | | Brasses. | | | | | | | | | Bolts. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | No. | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *t* | *u* | *v* | *w* |
| 16 | 8 | $3\frac{5}{8}$ | $5\frac{7}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $2\frac{1}{4}$ | 2 | $\frac{7}{8}$ | $2\frac{5}{8}$ | — | $4\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{7}{8}$ | 2 | $2\frac{1}{2}$ | — | $\frac{1}{4}$ |
| 20 | 10 | $4\frac{1}{2}$ | $7\frac{1}{4}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $2\frac{1}{2}$ | 2 | 1 | 3 | $1\frac{5}{8}$ | 5 | $\frac{3}{4}$ | $3\frac{1}{4}$ | $2\frac{5}{8}$ | 1 | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $5\frac{3}{4}$ | $\frac{1}{4}$ |
| 24 | 12 | $5\frac{1}{4}$ | $8\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | 2 | $\frac{5}{8}$ | $\frac{1}{2}$ | $2\frac{3}{4}$ | 2 | $1\frac{1}{8}$ | $3\frac{5}{8}$ | $1\frac{7}{8}$ | $6\frac{1}{8}$ | $\frac{7}{8}$ | 4 | 3 | $1\frac{1}{4}$ | $3\frac{1}{8}$ | $3\frac{3}{4}$ | $7\frac{1}{4}$ | $\frac{1}{4}$ |
| 28 | 14 | $6\frac{3}{8}$ | $9\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $3\frac{1}{4}$ | 2 | $1\frac{1}{4}$ | $4\frac{1}{4}$ | $2\frac{3}{16}$ | $6\frac{5}{8}$ | 1 | $4\frac{3}{4}$ | $3\frac{3}{8}$ | $1\frac{3}{8}$ | $3\frac{5}{8}$ | $4\frac{1}{4}$ | $7\frac{3}{4}$ | $\frac{1}{4}$ |
| 32 | 16 | 7 | $10\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $3\frac{5}{8}$ | 2 | $1\frac{1}{4}$ | $4\frac{3}{4}$ | $2\frac{3}{8}$ | $7\frac{5}{8}$ | 1 | $5\frac{5}{8}$ | $3\frac{3}{4}$ | $1\frac{1}{2}$ | $4\frac{1}{4}$ | $4\frac{3}{4}$ | $8\frac{1}{4}$ | $\frac{1}{4}$ |
| 36 | 18 | $7\frac{5}{8}$ | 12 | $\frac{5}{8}$ | $\frac{3}{4}$ | $2\frac{1}{8}$ | $3\frac{1}{4}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | 4 | 4 | $1\frac{1}{4}$ | $5\frac{3}{8}$ | $2\frac{7}{16}$ | $7\frac{3}{4}$ | $1\frac{1}{8}$ | $6\frac{1}{2}$ | $4\frac{1}{4}$ | $1\frac{3}{4}$ | $4\frac{3}{4}$ | $5\frac{1}{2}$ | $9\frac{1}{2}$ | $\frac{3}{8}$ |
| 40 | 20 | $8\frac{3}{4}$ | $13\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $2\frac{3}{8}$ | $3\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $4\frac{5}{8}$ | 4 | $1\frac{3}{8}$ | 6 | $2\frac{7}{8}$ | $8\frac{3}{8}$ | $1\frac{1}{4}$ | $7\frac{1}{4}$ | $4\frac{5}{8}$ | 2 | $5\frac{1}{4}$ | 6 | 10 | $\frac{3}{8}$ |
| 44 | 22 | 10 | $14\frac{3}{4}$ | $\frac{13}{16}$ | 1 | $2\frac{1}{2}$ | 4 | $\frac{7}{8}$ | $\frac{5}{8}$ | $5\frac{1}{4}$ | 4 | $1\frac{3}{8}$ | $6\frac{3}{4}$ | 3 | $8\frac{3}{4}$ | $1\frac{1}{4}$ | $7\frac{3}{4}$ | 5 | $2\frac{1}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{2}$ | $11\frac{1}{2}$ | $\frac{3}{8}$ |

All the Dimensions are given in Inches.

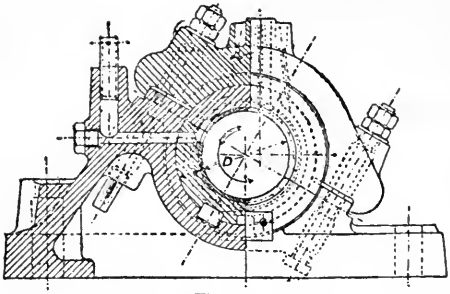


Fig. 146.

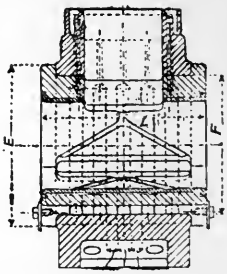


Fig. 147

Figs. 146, 147 show an example of inclined main bearing for high speed rope pulley, and is arranged for water circulation.

### Crank Shafts, Cranks, and Crank Discs.

Crank shafts were usually made of wrought iron, but now almost always of mild steel. For very large marine engines they are built up of steel, often Whitworth's compressed steel, and are made hollow to save weight; the diameter of the hollow being about ·6 of the external diameter of the shaft. Fig. 148 shows a built-up hollow crank.

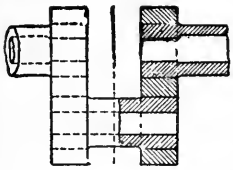


Fig. 148.

In high speed engines the weight of the connecting rod and crank should be balanced.

Let $W_1$ = the necessary balance weight.
$R$ = radius of the centre of gravity of the balance weight.
$W_2$ = weight of the crank pin plus half the weight of the connecting rod.
$r$ = the radius of the crank.
$W_3$ = weight of the piston, piston rod and crosshead.

Then for horizontal engines

$$W_1 = W_2 \frac{r}{R};$$

for vertical engines

$$W_1 = \tfrac{2}{3}(W_2 + W_3)\frac{r}{R};$$

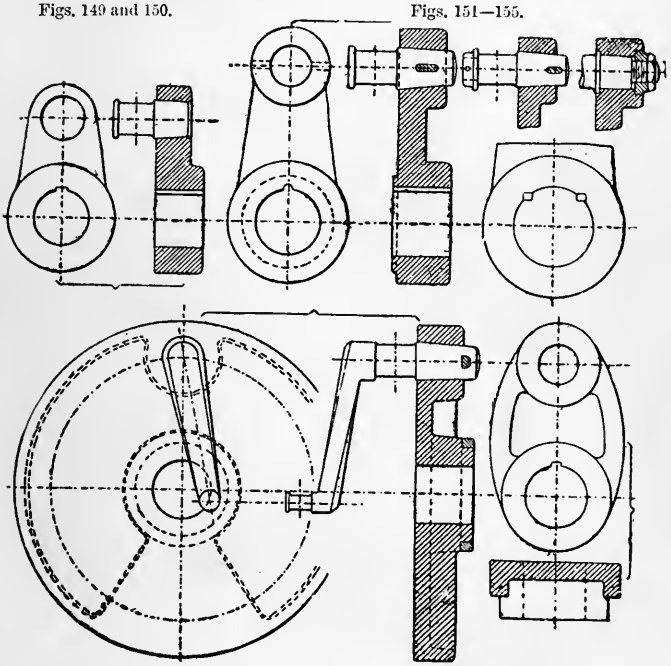
for locomotives it may be taken that

$$W_1 = W_2 \frac{r}{R}.$$

The balance weight should act in the same plane in which the parts to be balanced move ; hence it is wrong to balance the crank, connecting rod, piston, and crosshead by applying the balance weight to the fly-wheel. The employment of crank discs, figs. 160, 163, although somewhat easy to balance, is often objectionable on account of their acting as resonant bodies, and tend to magnify the noise caused by any knock in the engine.* A balanced crank disc is shown in figs. 156, 157.

**Cranks, Crank Discs, Slotted out and Bent Crank Shafts.**

Figs. 149 and 150. Figs. 151—155.



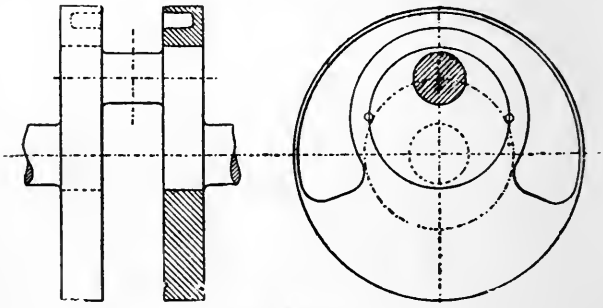
Figs. 156 and 157. Figs. 158 and 159.

Figs. 149, 150, show a form of ordinary crank, formerly made of cast iron ; figs. 151—155, a crank of wrought iron or cast steel ; figs.

* This may be true in some cases, but if the disc is sufficiently massive the effect is not very noticeable, especially if the balance weight is applied as is shown in figs. 182, 184.—Ed.

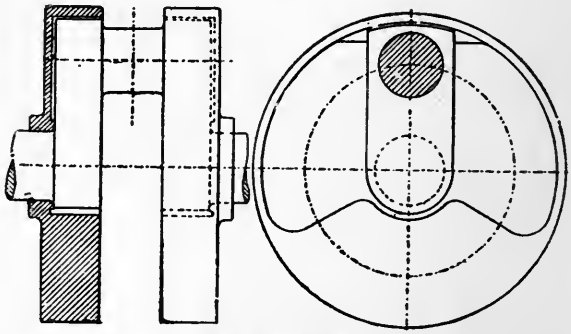
156, 157, a crank disc of cast iron ; figs. 158, 159, a crank of either cast iron or cast steel, the former material is not now much used, except in small cheap engines.

### Crank Shafts with Balance Weights.



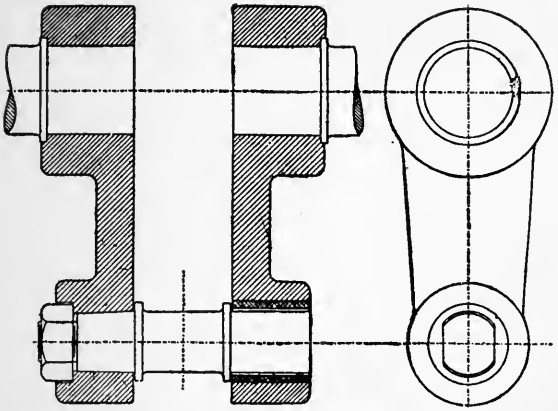
Figs. 160 and 161.

Figs. 160, 161, show a slotted or machined-out crank, with disc balance weights applied in a special manner to the round cheeks of the crank dip.



Figs. 162 and 163.

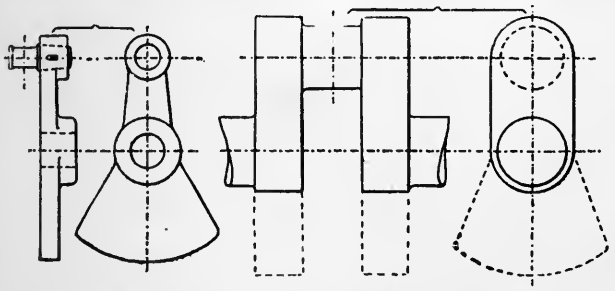
Figs. 162, 163, show an arrangement for applying the balance weights to the cheeks of an ordinary slotted-out crank.



Figs. 164 and 165.

Figs. 164, 165, show a wrought-iron or steel crank, with the crank pin free in one side of the crank; this type is much used for paddle engines, the engine crank shaft being separate from the paddle-wheel shafts, the latter being driven by the crank pin as shown, the left crank being on the engine shaft, the right-hand one on the paddle-wheel shaft.

## Cranks, Crank Discs, Slotted-out and Bent Crank Shafts.



Figs. 166 and 167. Figs. 168 and 169.

Figs. 166, 167 show a form of crank with balance weight in one piece; figs. 168, 169, a slotted-out crank a form much used in

"undertype" and other engines where it is desirable to save room in the width of the engine, this form being narrower than the common form of bent crank, which is almost exclusively used on portable engines, fig. 170. In the fig. 169 the slotted crank is shown with the sides shaped off concentric with the shaft and pin respectively at the two ends, but it is usual to turn these ends in the lathe on a centre, midway between the crank pin and shaft centres.

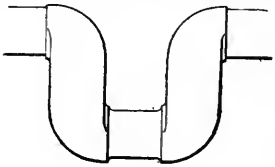


Fig. 170.

## Crank Shafts.

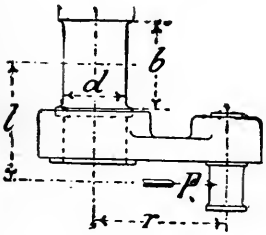



Fig. 171.

Particulars of the neck or journal.

In fig. 171 :—

P = Pressure on piston in lbs. ;
$M_b$ = P$l$ = the bending moment in inch or foot lbs. ;
$M_d$ = P$r$ = the turning moment in inch or foot lbs. ;
$k$ = the stress on the material in pounds per square inch ;

so the ideal bending moment (if, as usually the case, $M_b < M_d$) $(M_b)_i = \cdot 625\ M_b + \cdot 6\ M_d = W k$.

Example.—An engine with piston $15\frac{3}{4}''$ diameter, stroke $27\frac{1}{2}''$, $l = 13\frac{3}{4}''$, $p = 103$ lbs. per square inch, P = 20064 lbs.

$(M_b)_i = (\cdot 625 \times 20064 \times 13 \cdot 75 + 20064 \times \cdot 6 \times 13 \cdot 75) \div 12 = 28400$ foot lbs., or 340600 inch lbs.

The stress on the metal may be taken as $k = 9960$ lbs., or 4·4 tons per square inch, this gives the resistance moment

$$W = \cdot 1\ d^3 = \frac{340600}{9960} = 34 \cdot 0$$

$$d = 6 \cdot 9 \text{ inches.}$$

**Material: Wrought Iron or Mild Steel.**

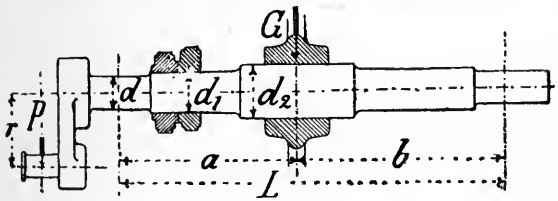



Fig. 172.

The diameter of the neck or journal being $d$, the diameters at the other parts of the shaft in fig. 172, $d_1 = 1{\cdot}15\ d$, $d_2 = 1{\cdot}4\ d$.

With usual proportions the stress on the metal at $d_2$ may be taken as from 2,800 to 5,600 lbs., or $1\frac{1}{4}$ to $2\frac{1}{2}$ tons per square inch

If G = the weight of the fly-wheel in pounds, the ideal bending moment for $d_2$, taking as before, page 50, $M_b < M_d$,

$$(M_b)_i = Wk = 0{\cdot}625\ G\ \frac{ab}{L} + 0{\cdot}6\ Pr.$$

## Cranks and Crank Pins.

Wrought-iron or cast steel cranks (fig. 173).

Length of boss $b$ = ·9 to $1{\cdot}3\ d$;

Thickness of metal W = ·4 to ·5 $d$;

The crank web will be exposed to a bending and twisting stress,

$$M_b = Pr\ ;\ M_d = Pa.$$

The diameter of the boss for the crank pin will be about $\frac{2}{3}$ of the larger boss for the shaft. The bore of the boss is made from $\frac{1}{1000}$ to $\frac{1}{2000}$ smaller than the end of the crank shaft, put on hot, in workshop language "shrunk on," and fitted with one or two keys.

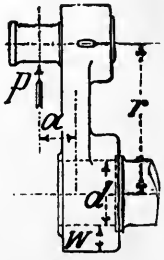



Fig. 173.

## Crank Shafts for Engines with Two Cylinders.

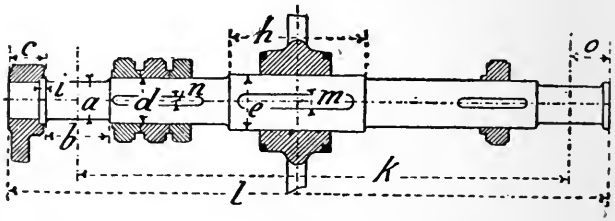



Fig. 174.

TABLE 12.—**Dimensions of Crank Shafts** (Fig. 174).

| Diam. of Piston and Stroke. | | Journal or Neck. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *h* | *i* | *k* | *l* | *m* | *n* | *o* |
| 20 | 10 | $4\frac{1}{2}$ | $7\frac{1}{4}$ | $3\frac{15}{16}$ | $5\frac{1}{4}$ | $5\frac{1}{4}$ | — | $\frac{1}{4}$ | 4′ 4″ | 5′ $3\frac{3}{4}$″ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $4\frac{1}{4}$ |
| 24 | 12 | $5\frac{1}{4}$ | $8\frac{1}{2}$ | 5 | 6 | 6 | — | $\frac{1}{4}$ | 4′ 10″ | 6′ $0\frac{1}{4}$″ | $1\frac{5}{8}$ | $\frac{5}{8}$ | 5 |
| 28 | 14 | $6\frac{3}{8}$ | $9\frac{1}{2}$ | $5\frac{3}{4}$ | $7\frac{3}{8}$ | $8\frac{3}{8}$ | 1′ 8″ | $\frac{3}{8}$ | 5′ 4″ | 6′ $8\frac{1}{8}$″ | 2 | $\frac{3}{4}$ | $5\frac{5}{8}$ |
| 32 | 16 | 7 | $10\frac{3}{4}$ | $6\frac{5}{8}$ | 8 | $9\frac{3}{8}$ | 2′ 0″ | $\frac{3}{8}$ | 5′ 10″ | 7′ $4\frac{3}{4}$″ | $2\frac{1}{4}$ | $\frac{3}{4}$ | $6\frac{3}{4}$ |
| 36 | 18 | $7\frac{5}{8}$ | 12 | $7\frac{3}{8}$ | $8\frac{5}{8}$ | $10\frac{5}{8}$ | 2′ 4″ | $\frac{1}{2}$ | 6′ 4″ | 8′ $0\frac{3}{8}$″ | $2\frac{5}{8}$ | $\frac{3}{4}$ | 7 |
| 40 | 20 | $8\frac{3}{4}$ | $13\frac{1}{4}$ | $8\frac{1}{8}$ | 10 | 12 | 2′ 8″ | $\frac{1}{2}$ | 7′ 0″ | 8′ $10\frac{1}{2}$″ | $2\frac{3}{4}$ | $\frac{3}{4}$ | $7\frac{3}{4}$ |
| 44 | 22 | 10 | $14\frac{3}{4}$ | $8\frac{3}{8}$ | $11\frac{1}{4}$ | $13\frac{1}{4}$ | 3′ 0″ | $\frac{1}{2}$ | 7′ 8″ | 9′ $8\frac{3}{4}$″ | 3 | $\frac{7}{8}$ | $8\frac{5}{8}$ |

All Dimensions are given in Feet and Inches.

## Crank Pins.

These are invariably of mild steel.

$d$ = diameter of pin in inches.

$b$ = length of pin in inches.

P = maximum pressure on piston in lbs.,

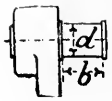


Fig. 175.

$$\text{then } M_b = P\frac{b}{2} = Wk = \cdot 1\, d^3 k.$$

The stress $k$ may be taken as from 6,720 to 11,200 lbs. or 3 to 5 tons per square inch. In order to avoid heating, the crank pin is usually made larger than given by the above formula. Let $p = \frac{P}{db}$ = the pressure per square inch in lbs. on the surface of the crank pin and $v = \frac{d\pi n}{12}$ = speed of crank pin surface in feet per minute, then for ordinary workmanship $p \leqq 1{,}130$ lbs. per square inch $vp \leqq 845$. With very high class workmanship we may go higher: see table on page 63.

Methods of fixing crank pins into the crank arm.—A very usual method is with cone and key (fig. 177), the pin being shrunk in, the taper of the cone being about 1 in 32. There is always difficulty in boring a tapered hole and making a pin to be an exact fit, an easier and better method of fixing crank pins is by making the pin with a collar and turning the shank parallel to fit a parallel hole in the crank arm, the pin can, when small, be secured by riveting the end over or by a key transversely through crank arm and pin, but in all cases the pin should be shrunk in, or squeezed in with a hydraulic press. A special method of fixing the pin is shown in fig. 176, which also shows an elaborate system of lubrication.

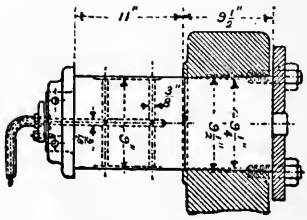
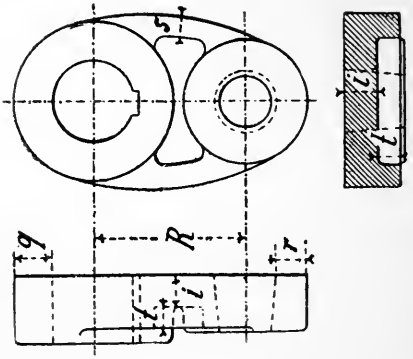
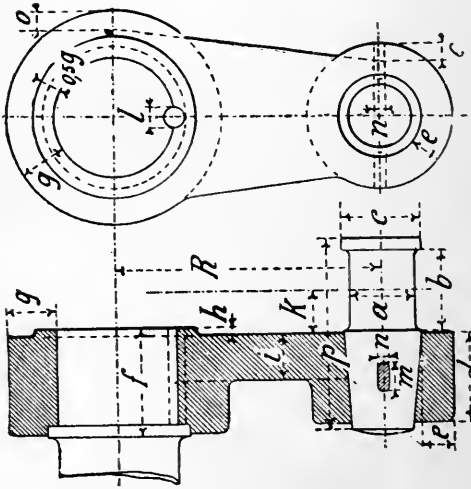


Fig. 176.




Figs. 179—181.



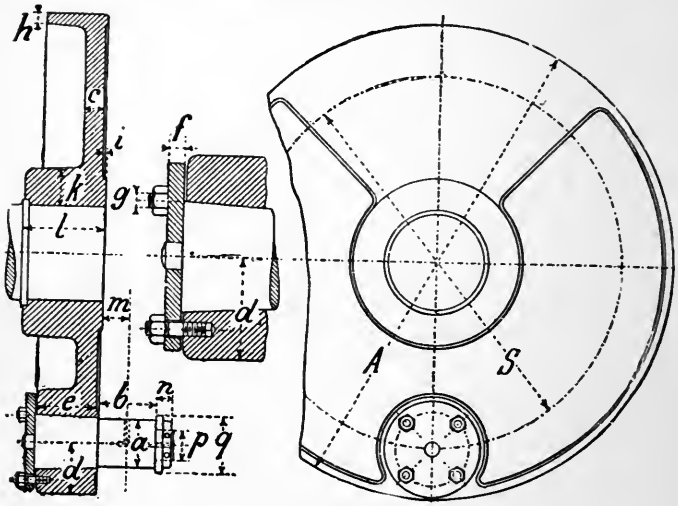

Figs. 177 and 178.

TABLE 13.—**Dimensions of Cranks and Crank Pins** (Figs. 177—181).

| Diameter of Piston, Stroke and Radius of Crank. | | | Wrought iron or cast steel. | | | | | | | | | | | | | | Cast iron. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | R | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* |
| 20 | 10 | 10 | $2\frac{5}{8}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $3\frac{15}{16}$ | 2 | $\frac{5}{16}$ | $1\frac{3}{4}$ | $1\frac{11}{16}$ | $\frac{3}{4}$ | 1 | $\frac{3}{8}$ | $\frac{3}{4}$ | 7 | 2 | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| 24 | 12 | 12 | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $3\frac{5}{8}$ | 4 | $1\frac{3}{8}$ | 5 | $2\frac{3}{8}$ | $\frac{3}{8}$ | 2 | $1\frac{7}{8}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $\frac{7}{16}$ | $\frac{7}{8}$ | $8\frac{1}{4}$ | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ |
| 28 | 14 | 14 | $3\frac{1}{4}$ | $4\frac{1}{4}$ | 4 | $4\frac{3}{8}$ | $1\frac{1}{2}$ | $5\frac{3}{4}$ | $2\frac{5}{8}$ | $\frac{7}{16}$ | $2\frac{1}{4}$ | $2\frac{3}{16}$ | 1 | $1\frac{3}{8}$ | $\frac{1}{2}$ | 1 | $9\frac{1}{2}$ | $2\frac{5}{8}$ | 2 | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| 32 | 16 | 16 | $3\frac{3}{4}$ | $4\frac{5}{8}$ | $4\frac{5}{8}$ | $4\frac{3}{4}$ | $1\frac{3}{4}$ | $6\frac{5}{8}$ | $2\frac{7}{8}$ | $\frac{7}{16}$ | $2\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $\frac{9}{16}$ | 1 | $10\frac{1}{4}$ | 3 | $2\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ |
| 36 | 18 | 18 | $4\frac{1}{4}$ | $5\frac{1}{4}$ | 5 | $5\frac{1}{4}$ | 2 | $7\frac{3}{8}$ | $3\frac{1}{4}$ | $\frac{1}{2}$ | 3 | $2\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $11\frac{1}{4}$ | — | — | — | — |
| 40 | 20 | 20 | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $2\frac{1}{4}$ | $8\frac{1}{8}$ | $3\frac{1}{2}$ | $\frac{1}{2}$ | $3\frac{3}{8}$ | 3 | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{11}{16}$ | $1\frac{1}{4}$ | $12\frac{1}{2}$ | — | — | — | — |
| 44 | 22 | 22 | $5\frac{1}{4}$ | $6\frac{3}{8}$ | $6\frac{1}{4}$ | $6\frac{3}{8}$ | $2\frac{3}{8}$ | $8\frac{3}{8}$ | $3\frac{3}{4}$ | $\frac{9}{16}$ | 4 | $3\frac{5}{16}$ | $1\frac{3}{8}$ | 2 | $\frac{3}{4}$ | $1\frac{1}{4}$ | $13\frac{1}{2}$ | — | — | — | — |

All Dimensions are given in Inches.

## Crank Discs of Cast Iron.




Figs. 182—184.

TABLE 14.—**Dimensions of Crank Discs** (Figs. 182—184).

| Diameter of piston and stroke. | | | Crank Pin. | | | | | | Bolts. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | A | *a* | *b* | *c* | *d* | *e* | *f* | No. | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *p* | *q* |
| 16 | 8 | 22 | $2\frac{1}{2}$ | $3\frac{1}{2}$ | $1\frac{1}{8}$ | 3 | 3 | $\frac{3}{8}$ | 3 | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{1}{8}$ | 2 | 4 | $1\frac{3}{4}$ | 1 | $1\frac{3}{4}$ | 3 |
| 20 | 10 | 26 | $2\frac{3}{4}$ | 4 | $1\frac{1}{4}$ | 3 | $3\frac{1}{2}$ | $\frac{7}{16}$ | 3 | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{1}{4}$ | $2\frac{1}{4}$ | 5 | $1\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{7}{8}$ | $3\frac{1}{2}$ |
| 24 | 12 | 31 | $3\frac{1}{4}$ | $4\frac{1}{2}$ | $1\frac{3}{8}$ | $3\frac{1}{2}$ | 4 | $\frac{1}{2}$ | 3 | $\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $2\frac{1}{2}$ | 6 | 2 | $1\frac{1}{4}$ | $2\frac{1}{4}$ | 4 |
| 28 | 14 | 36 | $3\frac{3}{4}$ | 5 | $1\frac{5}{8}$ | 4 | $4\frac{1}{2}$ | $\frac{9}{16}$ | 4 | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{3}{8}$ | $2\frac{3}{4}$ | 7 | $2\frac{1}{8}$ | $1\frac{3}{8}$ | $2\frac{5}{8}$ | $4\frac{1}{2}$ |
| 32 | 16 | 41 | $4\frac{1}{8}$ | $5\frac{1}{2}$ | $1\frac{3}{4}$ | $4\frac{1}{2}$ | 5 | $\frac{5}{8}$ | 4 | $\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{3}{8}$ | 3 | $7\frac{1}{2}$ | $2\frac{3}{8}$ | $1\frac{1}{2}$ | $2\frac{7}{8}$ | 5 |
| 36 | 18 | 46 | $4\frac{3}{4}$ | 6 | 2 | 5 | $5\frac{1}{2}$ | $\frac{11}{16}$ | 4 | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $3\frac{1}{2}$ | 8 | $2\frac{1}{2}$ | $1\frac{3}{4}$ | $3\frac{1}{4}$ | $5\frac{1}{2}$ |
| 40 | 20 | 51 | 5 | $6\frac{1}{2}$ | $2\frac{1}{8}$ | $5\frac{1}{2}$ | 6 | $\frac{3}{4}$ | 4 | $\frac{3}{4}$ | 1 | $\frac{1}{2}$ | 4 | $8\frac{1}{2}$ | $2\frac{3}{4}$ | 2 | $3\frac{1}{2}$ | 6 |

### Preparation of Crank Pins in Special Cases.

Crank pins are sometimes case-hardened and ground up true in a grinding machine. This has been done in America, and also in Germany and other countries. The journals in the Allen engine by Whitworth were ground up perfectly true; no doubt this is conducive to cool running, but with crank pins the heating is not always caused by want of truth in the form of the pin, but probably from the pin not being perfectly in line with the crank shaft.

### Lubrication of Crank Pins.

In small engines the necessary lubrication is obtained from an oil cup in the connecting rod end (fig. 185).

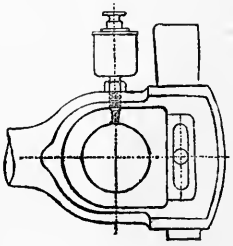


Fig. 185.

An arrangement for oiling the crank pin whilst the engine is running is shown in fig. 186. The oil cup is supported on the guard rail of the engine. The oil from the cup runs down a tube into a hollow ring at the end of a tube fixed into the crank pin. This hollow ring receives the oil which by centrifugal force makes its way through the holes in the crank pin, and thus supplies the pin

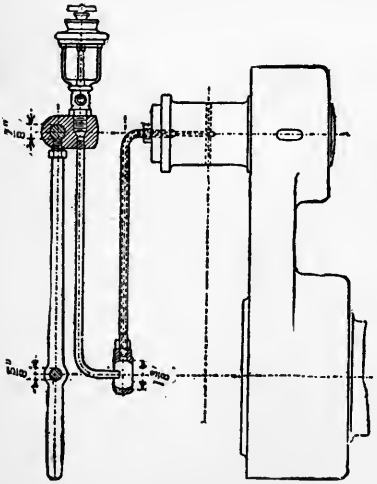


Fig. 186.

and connecting rod end with oil. Two other methods of lubricating with special grease are shown in figs. 187, 188, one with the "Stauffer"

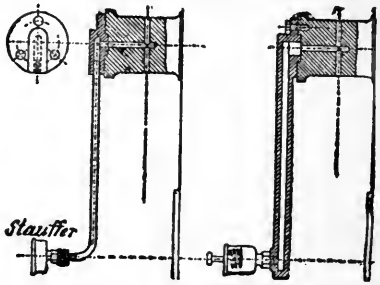



Fig 187. Fig. 188.

grease cup. The cap of this cup is screwed down by hand, and forces the grease along the tube to the pin.

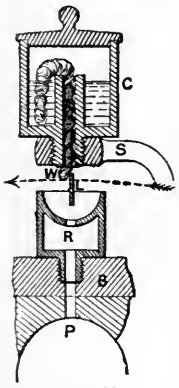



Fig 189.

Another method much used in large engines is shown in fig. 189. The oil cup, C, is supported on a wrought-iron standard carried up from the main bearing pedestal, so as to stand just over the crank pin when at the highest position. A cotton wick is provided in the cup, and is allowed to project through the bottom of the cup far enough to be wiped by the lip, L, in the cup R, fixed to the connecting rod end, B; at every revolution of the crank a small quantity of oil is wiped off by the lip, and falls down the oil hole to the crank pin, P. This method answers very well with engines running at ordinary speed, is very simple and inexpensive, and easily kept clean, there being no long pipes through which the oil must pass, and which frequently get stopped up with gummy matter and dirt.

### Slotted or Machined-out Cranks.

Formerly these were forged solid out of wrought iron, and then the dip drilled and slotted out; now they are usually made of mild steel, and machined out to the required form and

dimensions. Small cranks are occasionally cast to form from a pattern in steel.*

Fig. 190.

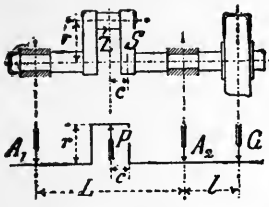



Fig. 191.

Fig. 192.

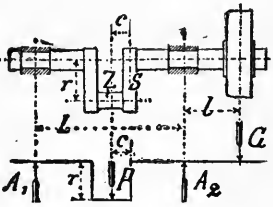



Fig. 193.

Let P = the pressure on the crank pin in lbs.
G = the weight of the fly-wheel in lbs.

**(a.) Single Crank Shaft as in the above figs. 190, 193.**

The maximum supported pressure is first to be calculated.

In figs. 190, 191—

$$A_1 = \frac{P \cdot \frac{L}{2} + G \cdot l}{L} = \frac{P}{2} + G\,\frac{l}{L} \quad . \quad . \quad (3)$$

In figs. 192, 193—

$$A_2 = \frac{P \cdot \frac{L}{2} + G\,(L + l)}{L} = \frac{P}{2} + G + G\,\frac{l}{L} \quad . \quad (4)$$

For calculating the crank cheeks or dips, S, imagine the right-hand cheek as rigidly fixed ; then in figs. 190, 191—

$$\text{I.} \begin{cases} M_b = A_1\left(\frac{L}{2} + c\right) - Pc \quad . \quad . \quad . \quad (5) \\ M_d = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad (6) \end{cases}$$

* There is some risk of confusion in speaking of "mild steel," "cast steel," and "steel castings," or "cast in steel." Generally speaking "mild steel" means such steels as are worked up from open hearth or Bessemer ingots into bars, plates, angles, &c. Such steel is not supposed to harden perceptibly when heated and quenched in cold water. "Cast steel" is a somewhat vague term, but may be generally taken to mean steel worked up from ingots made from melted shear steel, and is usually highly carbonized, and capable of being hardened in the ordinary way. One kind of this steel is known as tool steel. "Cast in steel" or "steel castings" means that the object is actually cast in form from melted steel poured into a mould. Steel castings of the very best quality are often advertised as "crucible steel," meaning obviously that the steel is melted in crucibles, and poured from them into the mould. Other more direct processes than this are used for large steel castings.

When turned 90°—

$$\text{II.}\begin{cases} M_b = Pr & \ldots\ldots\ldots\ldots (7) \\ M_d = A_1\left(\frac{L}{2} + c\right) - Pc & \ldots\ldots (8) \end{cases}$$

To calculate the cross section, that value is to be introduced which, according to equations I. or II., gives the $(M_b)_i$.

$$\text{For the pin Z take}\begin{cases} M_b = A_1 \frac{L}{2} & \ldots\ldots\ldots (9) \\ M_d = 0. \end{cases}$$

$$\text{At the bearing } A_2\begin{cases} M_b = Gb & \ldots\ldots\ldots (10) \\ M_d = Pr & \ldots\ldots\ldots (11) \end{cases}$$

$M_b$ and $M_d$ may be combined into the ideal bending moment $(M_b)_i$ according to the formula given on page 50.

*Example.*—Calculation from above formulæ for the shaft of an engine with piston 8″ diameter, and stroke $11\frac{3}{4}$″, working pressure 75 lbs. per square inch. The engine frame is shown on page 20, fig. 54.

$$P = 3306 \text{ lbs.},\ G = 880 \text{ lbs.},\ r = \frac{11{\cdot}75}{2} = 5{\cdot}875 \text{ inches.}$$

$$L = 29{\cdot}5 \text{ inches},\ l = 8{\cdot}67 \text{ inches},\ c = 2{\cdot}95 \text{ inches.}$$

$$A_1 = \frac{3306}{2} + 880\,\frac{8{\cdot}67}{29{\cdot}5} = 1912 \text{ lbs.}$$

$$A_2 = \frac{3306}{2} + 880 + 880\,\frac{8{\cdot}67}{29{\cdot}5} = 2792 \text{ lbs.}$$

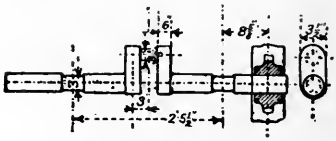


Fig. 194.

For the crank cheeks or dips—

$$\text{II.}\begin{cases} M_b = 3306 \times 5{\cdot}875 = 19423 \text{ inch-lbs.}, \\ M_d = 1913\,(14{\cdot}76 + 2{\cdot}95) - 3306 \times 2{\cdot}95 = 24110 \text{ inch-lbs.}; \end{cases}$$

then $(M_b)_i = {\cdot}625 \times 19423 + {\cdot}6 \times 24126 = 12139 + 14466 =$ 26605 inch-lbs.

The cross-section of the crank cheek $= 3{\cdot}5'' \times 2{\cdot}4'' = 8{\cdot}4$ sq. ins. the value of the smallest cross-section of metal.

$$\frac{26605}{8{\cdot}4} = 3170 \text{ inch-lbs. per square inch nearly.}$$

For the bearing $A_2$, figs. 190—193,

$$(M_b)_4 = \cdot 625 \times 880 \times 8\,625 + \cdot 6 \times 3306 \times 5{\cdot}9 = 4744 + 11706 = 16450 \text{ inch-lbs.}$$

Cross-section = area of 2·95 inches = 6·83 sq. ins.

$$\frac{16450}{6{\cdot}83} = 2406 \text{ inch-lbs. per square inch.}$$

For the crank pin, Z, $M_b = 1913 \times \frac{29{\cdot}5}{2} = 28216$ inch-lbs.

Cross-section = area of 3·14 = 7·74

$$\frac{28216}{7{\cdot}74} = 3644 \text{ inch-lbs. per square inch.}$$

### (b.) Double Crank Shafts.

Also here the first point to be determined is the pressure on the bearings; for simple calculation the pressure on the two pistons may be taken as equal.

Fig. 195.

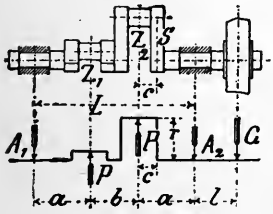



Fig. 196.

Fig. 197.

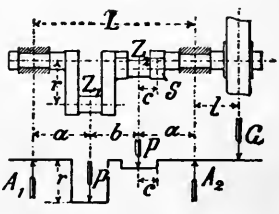



Fig. 198.

In figs. 195, 196,

$$A_1 = \frac{Pa + P(a+b) + Gl}{L} = P + G\frac{l}{L} \quad . \quad . \quad . \quad (12)$$

In figs. 197, 198,

$$A_2 = \frac{Pa + P(a+b) + G(L+l)}{L} = P + G + G\frac{l}{L} \quad . \quad (13)$$

The twisting and bending moments for the cheeks, S, crank pin, $Z_2$, and bearing, $A_2$, can be determined by the same method as above.

A useful formula for calculating the diameter of a crank shaft is as follows: $d = \sqrt[3]{\frac{HP}{N}} \times c$. Where N = number of revolutions per minute, $c$ = a constant based on practice. When using the somewhat vague term of "nominal" horse-power, the constant may be taken as 560; $d = \sqrt[3]{\frac{HP}{N}} \times 560$. When using indicated horse-power, the constant may be taken as 190; $d = \sqrt[3]{\frac{IHP}{N}} \times 190$, this will give ample strength for mild steel shafts.

**Methods of oiling Crank Pins of Bent and Slotted-out Cranks.**—The usual method is based on that shown on page 57 fig. 185, where the crank pin is oiled through the connecting rod end. Another method, but certainly not so good, is shown in fig. 199, where a hole is drilled in the pin shown in dotted lines, and fed with oil by a cup fixed to a ring held concentric with the shaft. No doubt this would freely oil the pin, but the long holes through which the oil has to travel are liable to get choked up, and may do so without being noticed until the pin runs hot.

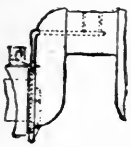


Fig. 199.

## Connecting Rods.

Of almost equal importance to the crank shaft main bearing is the connecting rod end which works on the crank pin. The desire to make a perfect connecting rod end has led to a large number of

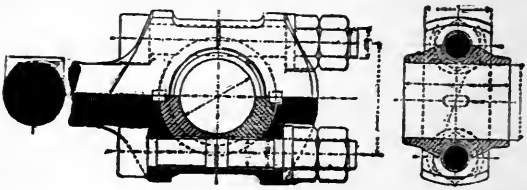


Fig. 200.

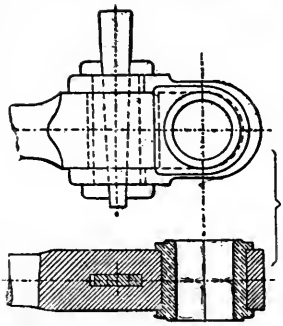
varieties being designed, but the general tendency has been to settle down into two or three types, such as the marine type with bolts, the strap and cotter type, the solid end type, and a few others for special cases.

Fig. 200 shows an example of connecting rod end fitted with bolts, and the seating faces of the brasses of spherical form to allow of slight self-adjustment should any part be out of truth. The example is taken from a pumping engine, with a crank pin 9·84 inches diameter.

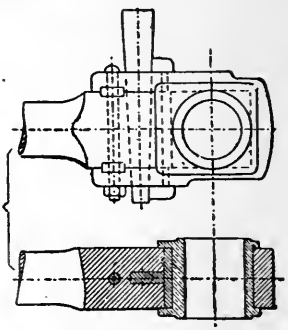
TABLE 15.—**Engine Crank Pins from Actual Practice.**
(Kiesselbach.)

| Diam. of Cyl. in. | Stroke in. | Revs. per min. | $d$ ins. | $l$ ins. | P lbs. | $p$ lbs. p. per. sq. in. | $p\,v$ ft. lbs. p. sec. &sq.in. | Material of bearings. | Machinery driven by Engine. |
|---|---|---|---|---|---|---|---|---|---|
| 17·7 | 27·5 | 66 | 4·5 | 4·7 | 22500 | 1113 | 1381 | Babbit | Electric light |
| 23·6 | 43·3 | 75 | 8·5 | 13·0 | 30900 | 280 | 779 | Gun metal | Roller mills |
| 23·6<br>35·4 | 41·1 | 60 | 6·1 | 6·1 | 38200 | 1027 | 1640 | Babbit | Flour mills |
| 23·6<br>39·3 | 39·4 | 120 | 5·1 | 5·1 | 24700 | 950 | 1537 | Gun metal | Roller mills |
| 25·6 | 25·6 | 150<br>180 | 5·9 | 6·3 | 28200 | 750 | 2896<br>3475 | Babbit | Roller mills |
| 27·5 | 39·4 | 100 | 6·3 | 6·7 | 40400 | 957 | 2631 | Babbit | Roller mills |
| 31·5 | 47·2 | 80 | 7·1 | 8·6 | 41900 | 686 | 1700 | Gun metal | Roller mills |
| 35·4 | 53·1 | 80 | 7·9 | 9·8 | 65300 | 861 | 2374 | Gun metal | Roller mills |
| 49·2 | 49·2 | 80<br>90 | 9·8 | 11·0 | 127800 | 1186 | 4057<br>4567 | Babbit | Roller mills |

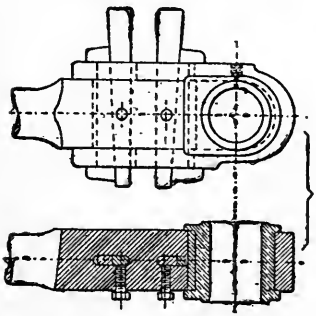
## Connecting Rod Ends.



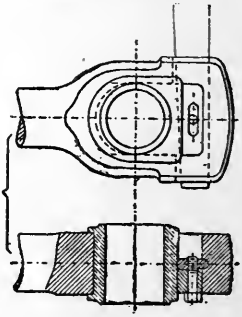
Figs. 201 and 202.



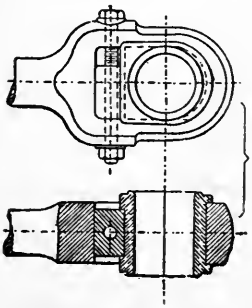
Figs. 203 and 204.



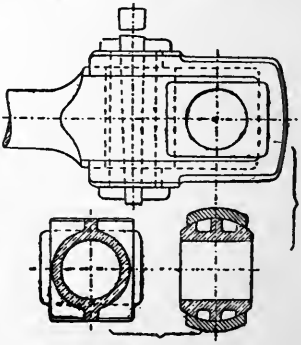
Figs. 205 and 206.



Figs. 207 and 208.



Figs. 209 and 210.



Figs. 211 and 212.

Figs. 201, 203, 205 and 211 show varieties of the connecting rod ends known as the "strap, gib and cottar" or "butt" end, a form much used on locomotives and other engines, it is easy of adjustment, and occupies but little space. Figs. 207 and 209 show two varieties of that kind known as the "solid" end; and this form is probably the lightest in weight of all ordinary ends, but can only be used with crank pins on discs or crank arms. On account of the end being in one piece with the rod, it can only be taken off the pin by pulling outwards. It is a very good form, and very safe from breakdowns and other mishaps.

With fig. 203, when the cottar is driven down to take up wear, the rod is lengthened, that is, the distance from centre to centre of brasses in the two ends is increased; in fig. 201 the reverse is the case; in the solid end, fig. 209, the length is increased, and in fig. 207 diminished. Sometimes connecting rods are made with one end adjusting in the opposite sense to the other end, this tends to keep the rod nearly to the normal length.

Fig. 213.

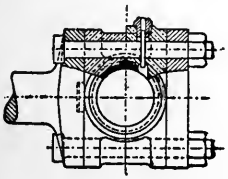


Fig. 214.

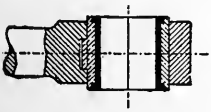


Fig. 215.

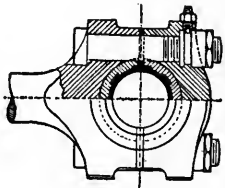


Fig. 216.

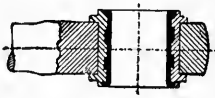
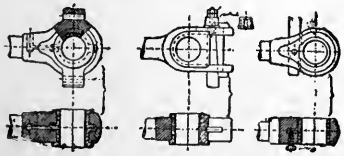
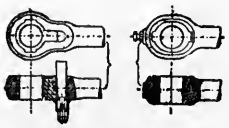


Fig. 213 shows a connecting rod end much used both for small and large engines; it is a good form and cheap to make. There is more brass in the form fig. 213 than in fig. 215, and fig. 215 is more used in large work, such as marine engines. In the above two figs. the "brasses" are lined with Babbit metal, and may sometimes be of cast iron or of cast steel, the latter is used by eminent marine engine builders.

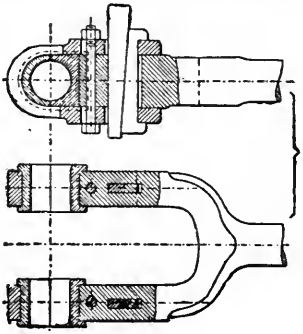


Figs. 217—219.

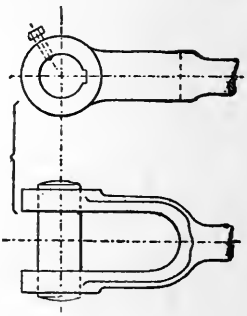


Figs. 220 and 221.

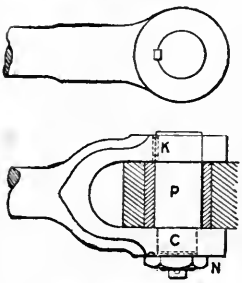
Figs. 217 to 221 show a variety of types used for the crosshead end of rod in small engines. Fig. 218 was formerly used on pump rods, and thus no doubt found its way on to some of the early steam engines. It is now very rarely used, at least for connecting rods.



Figs. 222 and 223.

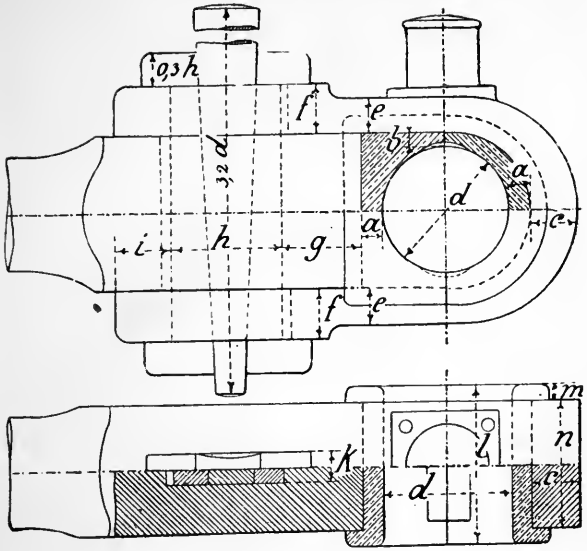


Figs. 224 and 225.




Figs. 226 and 227.

The crosshead end of a connecting rod has often to be made forked to embrace a solid crosshead. In some cases the brasses and adjustment are in the rod, as fig. 222, the pin being fixed in the crosshead; in other cases the brasses and adjustment are in the crosshead, and the pin fixed in the rod, as figs. 224, 226. Two methods of fixing the pin are shown, that in fig. 227 being by far the best. The pin is fixed by boring the two sides of the fork with conical holes of different sizes, so that the similar cones on the pin may be passed in from one side. This method, although good, is difficult to carry out in practice as it is almost impossible to make both sides a perfect fit, and to insure that the sides of the fork are not pulled in when the nut on the small end of the pin is tightened up (see fig. 269). In fig. 227 the pin is parallel, and one end, C, is smaller than the other part, P, to form a shoulder; the larger end is provided with a key, or feather, K, and the smaller end with a nut, N. The pin with the feather, K, is driven in tightly, and then the nut, N, screwed up hard; provided that the pin is well fitted in both sides (and about this there is no difficulty as both are parallel), this forms a good fixing, and experience has shown that it is easily drawn out and does not work loose.




Figs. 228 and 229.

TABLE 16.—**Dimensions of Connecting Rod Ends** (Figs. 228, 229).

| Crank Pin. | | NOTE.—All Dimensions are given in Inches. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *d* | *l* | *a* | *b* | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *m* | *n* |
| 2 | $2\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | 1 | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{1}{4}$ | $1\frac{7}{8}$ |
| $2\frac{1}{2}$ | $3\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | 1 | $\frac{5}{8}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $1\frac{7}{8}$ | 1 | $\frac{1}{2}$ | $\frac{5}{16}$ | $2\frac{3}{8}$ |
| $2\frac{3}{4}$ | $3\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{3}{4}$ |
| 3 | $4\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{4}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $3\frac{1}{2}$ |
| $3\frac{1}{2}$ | $4\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{7}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $3\frac{5}{8}$ |
| 4 | $5\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $3\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | 4 |
| $4\frac{1}{2}$ | $5\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $2\frac{3}{8}$ | $3\frac{5}{8}$ | 2 | 1 | $\frac{5}{8}$ | $4\frac{1}{2}$ |
| 5 | $6\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{5}{8}$ | 4 | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $5\frac{1}{8}$ |
| $5\frac{1}{2}$ | 7 | $\frac{3}{4}$ | $\frac{1}{2}$ | $2\frac{1}{8}$ | $1\frac{1}{2}$ | $2\frac{1}{8}$ | 3 | $4\frac{3}{4}$ | $2\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $5\frac{3}{4}$ |
| 6 | $7\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $2\frac{3}{8}$ | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $5\frac{1}{4}$ | $2\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $6\frac{1}{2}$ |
| $6\frac{1}{2}$ | $8\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{8}$ | $3\frac{3}{8}$ | $5\frac{5}{8}$ | 3 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $7\frac{1}{4}$ |
| 7 | 9 | 1 | $\frac{5}{8}$ | $3\frac{1}{8}$ | $1\frac{7}{8}$ | $2\frac{3}{4}$ | $3\frac{3}{4}$ | $6\frac{3}{8}$ | $3\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $7\frac{1}{2}$ |
| $7\frac{1}{2}$ | $9\frac{3}{4}$ | 1 | $\frac{5}{8}$ | $3\frac{3}{8}$ | 2 | $2\frac{7}{8}$ | 4 | $6\frac{3}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $8\frac{1}{4}$ |
| 8 | 10 | $1\frac{1}{8}$ | $\frac{5}{8}$ | $3\frac{5}{8}$ | $2\frac{1}{8}$ | 3 | $4\frac{1}{4}$ | $7\frac{1}{4}$ | $3\frac{7}{8}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ | $8\frac{1}{2}$ |

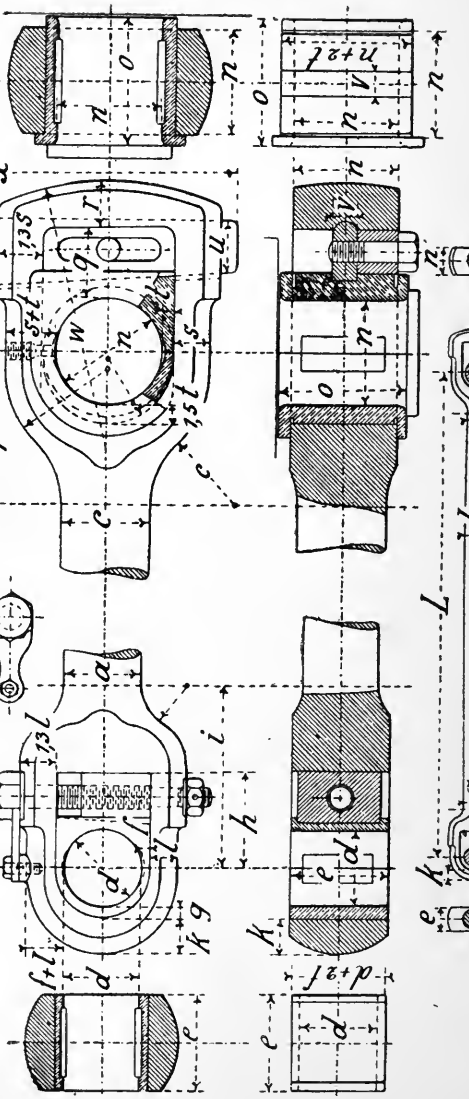


Fig. 230. Fig. 233. Fig. 232. Fig. 231 Fig. 234.

TABLE 17.—**Dimensions of Connecting Rods** (Figs. 230—234).

| Engines. | | Rod. | | | | Crosshead end. | | | | | | | | | Crank Pin end. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | L | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* | *x* |
| 12 | 6 | 32 | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $1\frac{3}{4}$ | $3\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | — | — | — | — | — | — | — | — | — | — |
| 16 | 8 | 42 | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $2\frac{1}{8}$ | 4 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | — | — | — | — | — | — | — | — | — | — |
| 20 | 10 | 50 | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{8}$ | 2 | $2\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $2\frac{5}{8}$ | $5\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $2\frac{5}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | 1 | $\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | 9 | 8 |
| 24 | 12 | 60 | 2 | $2\frac{5}{8}$ | $2\frac{3}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $2\frac{3}{4}$ | 6 | 1 | $\frac{7}{8}$ | $\frac{5}{8}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $4\frac{3}{8}$ | 2 | $1\frac{1}{4}$ | 1 | $\frac{5}{16}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | 10 | $9\frac{1}{2}$ |
| 28 | 14 | 70 | $2\frac{1}{4}$ | 3 | $2\frac{5}{8}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $3\frac{1}{4}$ | $6\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | $\frac{5}{8}$ | $3\frac{1}{4}$ | $4\frac{1}{4}$ | 5 | $2\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{5}{16}$ | $1\frac{3}{8}$ | 1 | 12 | 11 |
| 32 | 16 | 80 | $2\frac{3}{8}$ | $3\frac{1}{4}$ | $2\frac{3}{4}$ | 3 | 4 | $\frac{1}{4}$ | $\frac{3}{8}$ | $3\frac{5}{8}$ | $7\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $3\frac{3}{4}$ | $4\frac{5}{8}$ | $5\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{8}$ | 13 | 12 |
| 36 | 18 | 90 | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{1}{2}$ | 4 | $8\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $4\frac{1}{4}$ | $5\frac{1}{4}$ | $6\frac{1}{4}$ | $2\frac{5}{8}$ | $1\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{3}{8}$ | $1\frac{5}{8}$ | $1\frac{1}{4}$ | 14 | $13\frac{1}{2}$ |
| 40 | 20 | 100 | 3 | $3\frac{3}{4}$ | $3\frac{3}{8}$ | $3\frac{3}{4}$ | $4\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{1}{2}$ | $4\frac{3}{8}$ | 9 | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $6\frac{3}{4}$ | $2\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ | $1\frac{3}{8}$ | 16 | 15 |
| 44 | 22 | 110 | $3\frac{1}{4}$ | 4 | $3\frac{5}{8}$ | 4 | $5\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | $4\frac{5}{8}$ | $9\frac{5}{8}$ | $1\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | $7\frac{5}{8}$ | 3 | 2 | $1\frac{3}{4}$ | $\frac{1}{2}$ | 2 | $1\frac{1}{2}$ | 17 | 16 |

All Dimensions are given in Inches.

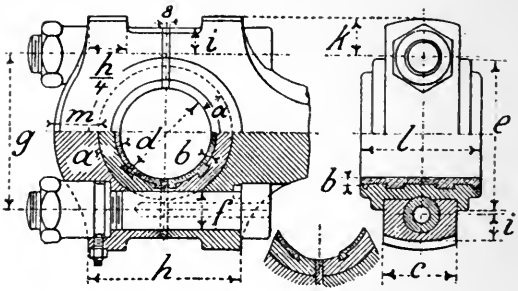
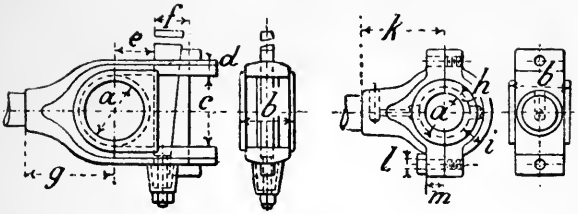



Fig. 235. Fig. 236.

TABLE 18.—**Dimensions of Connecting Rod Ends (Marine Type)** (Figs. 235, 236).

| Crank Pin. | | NOTE.—All Dimensions are given in Inches. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *d* | *l* | *a* | *b* | *c* | *e* | *f* | *g=h* | *i* | *k* | *m* |
| 2 | $2\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{16}$ | 2 | $4\frac{3}{8}$ | $1\frac{1}{8}$ | $4\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| $2\frac{1}{2}$ | 3 | $\frac{5}{8}$ | $\frac{3}{16}$ | $2\frac{1}{4}$ | $4\frac{3}{4}$ | $1\frac{1}{4}$ | $4\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ |
| $2\frac{3}{4}$ | $3\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{3}{16}$ | $2\frac{3}{8}$ | 5 | $1\frac{1}{4}$ | $5\frac{1}{4}$ | $\frac{7}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| $3\frac{1}{4}$ | 4 | $\frac{11}{16}$ | $\frac{3}{16}$ | $2\frac{3}{4}$ | $5\frac{5}{8}$ | $1\frac{3}{8}$ | $5\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ |
| $3\frac{1}{2}$ | $4\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{3}{16}$ | $3\frac{1}{4}$ | $6\frac{1}{4}$ | $1\frac{1}{2}$ | $6\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ |
| 4 | $5\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $3\frac{3}{8}$ | $6\frac{3}{4}$ | $1\frac{3}{4}$ | $7\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{7}{8}$ | 2 |
| $4\frac{1}{2}$ | $5\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $3\frac{3}{4}$ | $7\frac{3}{8}$ | $1\frac{7}{8}$ | $7\frac{3}{4}$ | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $2\frac{1}{4}$ |
| $4\frac{3}{4}$ | 6 | $\frac{7}{8}$ | $\frac{1}{4}$ | 4 | $7\frac{3}{4}$ | $2\frac{1}{8}$ | $8\frac{3}{8}$ | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ |
| $5\frac{1}{4}$ | $6\frac{5}{8}$ | 1 | $\frac{5}{16}$ | $4\frac{3}{8}$ | $8\frac{5}{8}$ | $2\frac{1}{4}$ | $9\frac{1}{4}$ | $1\frac{5}{8}$ | $2\frac{3}{8}$ | $2\frac{5}{8}$ |
| $5\frac{5}{8}$ | $7\frac{1}{4}$ | 1 | $\frac{5}{16}$ | $4\frac{3}{4}$ | $9\frac{1}{4}$ | $2\frac{3}{8}$ | $9\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ |
| 6 | $7\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{5}{16}$ | 5 | $9\frac{5}{8}$ | $2\frac{5}{8}$ | $10\frac{3}{8}$ | 2 | $2\frac{3}{4}$ | 3 |
| $6\frac{1}{2}$ | $8\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{5}{16}$ | $5\frac{3}{8}$ | $10\frac{3}{8}$ | $2\frac{3}{4}$ | $11\frac{1}{4}$ | $2\frac{1}{8}$ | $2\frac{7}{8}$ | $3\frac{1}{4}$ |
| $7\frac{1}{4}$ | $9\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{5}{16}$ | 6 | $11\frac{5}{8}$ | $3\frac{1}{4}$ | $12\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{5}{8}$ |
| 8 | 10 | $1\frac{3}{8}$ | $\frac{5}{16}$ | $6\frac{3}{4}$ | $12\frac{3}{8}$ | $3\frac{3}{8}$ | $13\frac{3}{4}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | 4 |




Figs. 237 and 238.

TABLE 19.—**Dimensions of small Connecting Rod Ends** (Figs. 237, 238).

| Engines. | | NOTE.—All Dimensions are given in Inches. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* |
| 12 | 6 | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $3\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $4\frac{3}{8}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $4\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ |
| 16 | 8 | $3\frac{1}{4}$ | $3\frac{5}{8}$ | $3\frac{7}{8}$ | $\frac{7}{8}$ | 2 | 2 | $4\frac{3}{4}$ | $\frac{5}{16}$ | $1\frac{1}{4}$ | $5\frac{1}{4}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ |

These types, especially fig. 237, are not much used now, having been superseded by those which are capable of being turned out by machine work, with as little hand work as possible.

### Connecting Rods.

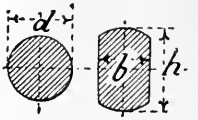
Wrought-iron rods of round or flattened cross section. Figs. 239, 240.

P = pressure on piston in lbs.

$l$ = length of rod in inches.

$d$ = diameter of round rod in inches at centre of length.

$m$ = constant for different speeds, see table 20, then




Figs. 239 and 240.

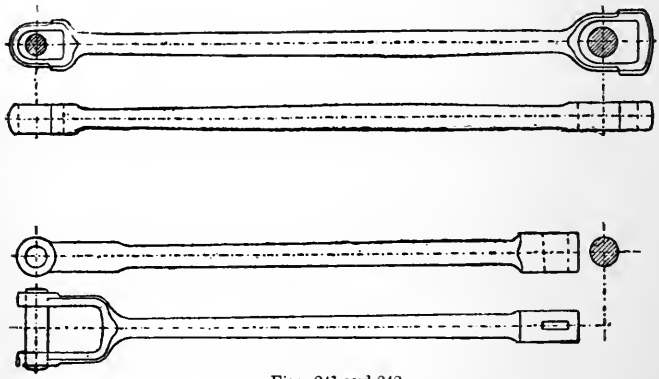
$$d = \cdot 0164 \sqrt[4]{m \,.\, \mathrm{P} \,.\, l^2}.$$

TABLE 20.

| Piston speed in feet per minute. | 200 | 400 | 600 | 800 |
|---|---|---|---|---|
| *m* | 30 | 20 | 15 | 10 |

With locomotives, $m$ may be taken from 10 to 6. The diameter of the rod at crosshead end is $\cdot 8d$, at the crank end $\cdot 9d$.

The rod when made of wrought iron is usually of round section, but sometimes of the flat-sided section shown in fig. 244. Of late years cast-steel rods of **I** section are coming largely into use, especially for small engines, and also in locomotives, fig. 245.



Figs. 241 and 242.

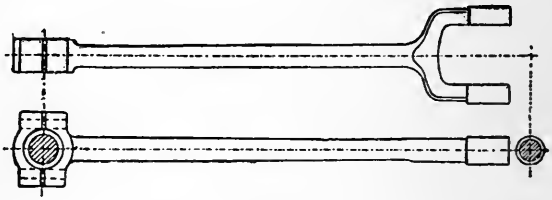
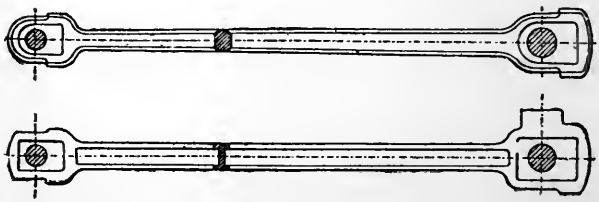


Fig. 243.



Figs. 244 and 245.

Conversion of round into rectangular cross section.

TABLE 21.

| $h : b$ | 1·5 | 1·75 | 2 | 2·25 | 2·5 |
|---|---|---|---|---|---|
| $b : d$ | ·79 | ·76 | ·74 | ·72 | ·7 |
| $h : d$ | 1·19 | 1·33 | 1·48 | 1·62 | 1·75 |

Example.—In an engine $P = 15432$ lbs., the length of the rod $l = 71$ inches, the piston speed = 400 feet per minute; for the round rod $d = \cdot0164 \sqrt[4]{20 \times 15432 \times 71^2} = 3{\cdot}23$ inches, for a rectangular rod with the proportion $h : b = 1{\cdot}75$, from the table $b : d = {\cdot}76$,

then $b = {\cdot}76 \times 3{\cdot}23 = 2{\cdot}45$ inches,
and $h = 1{\cdot}33 \times 3{\cdot}23 = 4{\cdot}29$ inches.

### Crossheads.

These are made in endless variety of form and construction and the materials used are cast iron, wrought iron and cast steel, the wearing surface of the guide blocks attached to the crossheads are almost invariably of cast iron. Formerly guide bars were often made circular, turned steel bars being much used on small engines, but now the bars are either flat or bored out, both systems having merits of their own. Possibly flat surfaces work with the least friction, other things being equal, but bored-out guides and turned crossheads have the merit of being made perfectly true with less difficulty than flat surfaces. The figures below show a variety of crossheads. The pressure on the guide surfaces may be from 30 to 45 lbs. per square inch.

Figs. 246, 247 are examples of American practice.

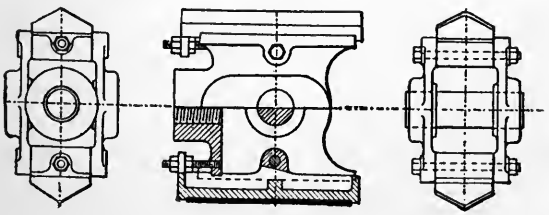


Fig. 246.

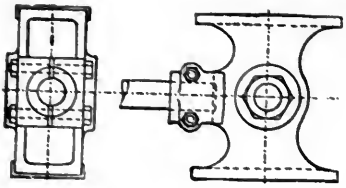


Fig. 247.

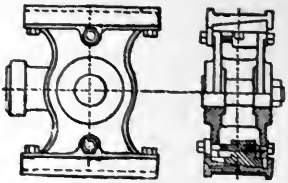


Fig. 248.

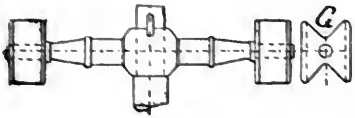



Fig. 249.

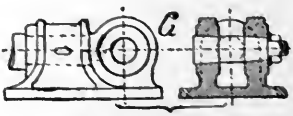



Fig. 250.

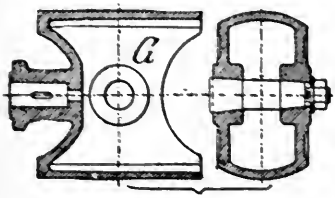



Fig. 251.

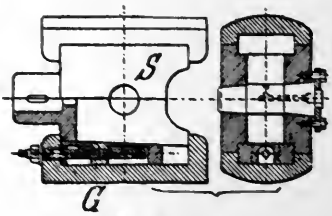



Fig. 252.

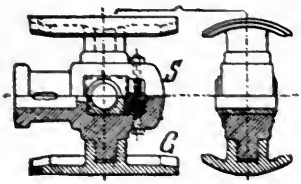



Fig. 253.

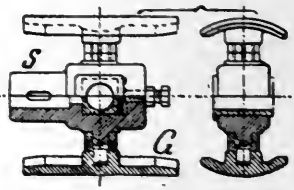



Fig. 254.

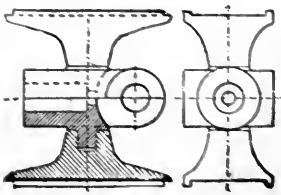


Fig. 255.

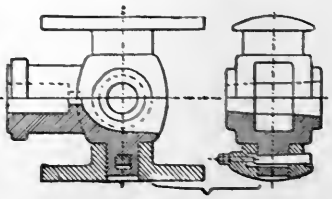


Fig. 256.

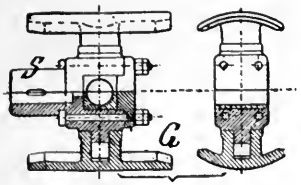



Fig. 257.

G. Cast iron.

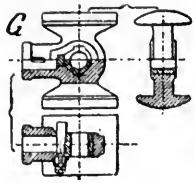



Fig. 258.

S. Wrought iron or cast steel.

### Crosshead Pin.

The maximum pressure on the surface of the pin is up to 1400 lbs. per square inch.* The length of the pin varies from two diameters down to 1·3 diameters. The crosshead pins are lubricated by automatic means for engines which have to make long runs, with an arrangement like that on page 58, fig. 189, for oiling the crank pin. See also fig. 259.

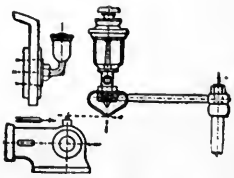


Fig. 259.

There are advantages and disadvantages in some of these types of crossheads with respect on the one hand to the guide blocks or slippers ; in the old types with two blocks and four bars, such as those shown in fig. 267, page 80, there are a number of parts and a great deal of labour in fitting up ; however, for a long time such crossheads, blocks, and bars held their own and were universally used ; now following the same lines of development as in engine frames, that is of making the structure in as few pieces as possible ; two bars, top and bottom, are almost universal, the guiding surfaces or bars being in one with the engine frame, and this lessens the labour and decreases the liability of error in fitting up.

In some cases, however, there is only one bar with the guide block embracing it all round ; this is common in locomotives, and has the merit of being easy of access. In marine engines and in some large land engines the crosshead is simple, as in fig. 250, and two strips bolted to the frame form the upper guide surfaces ; this is only used in land engines when they run one way continually, so that the pressure is always on the bottom bar, and when the engine is horizontal the guide block can be made to run in a bath of oil, a very effective way of lubricating.

* This is very high, a good English example giving only 850 lbs., with maximum boiler pressure on the piston.

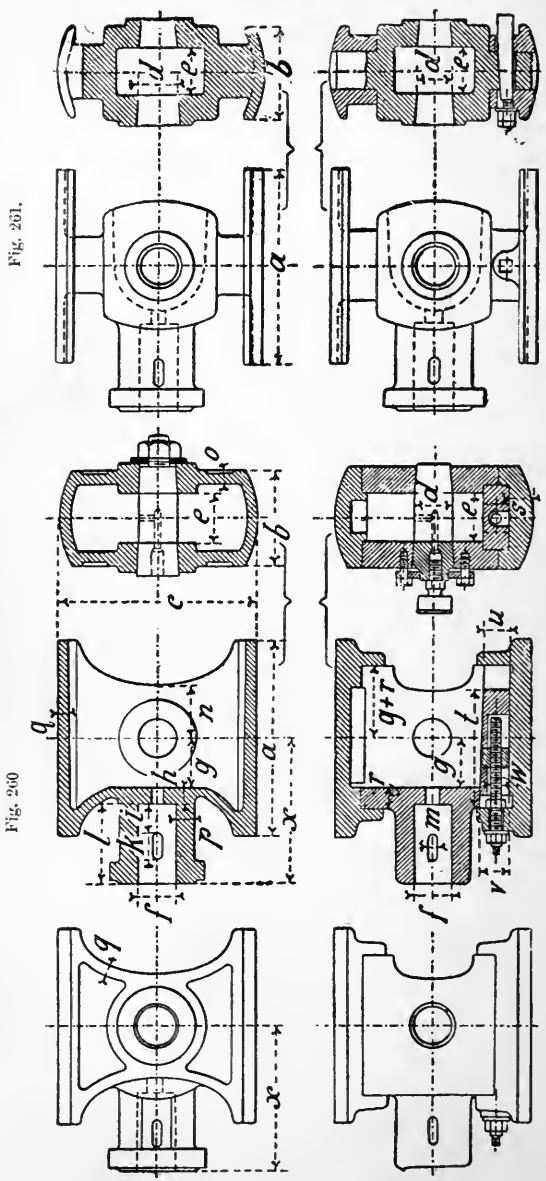
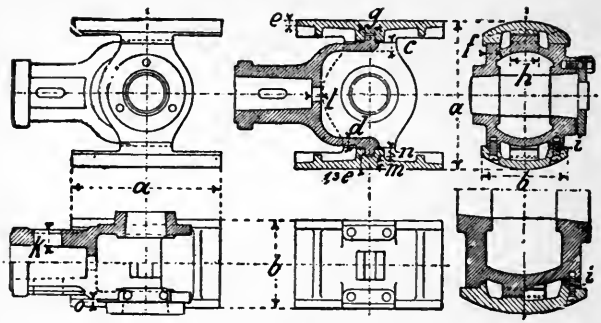


Fig. 260
Fig. 261.
Fig. 262.
Fig. 263.

TABLE 22.—**Dimensions of Crossheads** (Figs. 260—263) **for Engine Frame,** page 24.

| Engines. | | Cast Iron. | | | | | | | | | | | | | | | | Wrought Iron with Cast-iron Slippers. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* | *x* |
| 12 | 6 | 6 | $3\frac{5}{8}$ | 7 | $1\frac{3}{8}$ | $1\frac{3}{4}$ | 1 | 2 | $\frac{1}{2}$ | $\frac{3}{4}$ | 1 | $2\frac{3}{4}$ | $\frac{3}{8}$ | $1\frac{3}{4}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | — | — | — | — | — | — | $5\frac{1}{4}$ |
| 16 | 8 | $7\frac{5}{8}$ | $4\frac{1}{2}$ | 9 | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $1\frac{1}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $3\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | — | — | — | — | — | — | $6\frac{1}{2}$ |
| 20 | 10 | $8\frac{3}{4}$ | 5 | 11 | 2 | $2\frac{3}{4}$ | $1\frac{1}{2}$ | $2\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $4\frac{1}{8}$ | $\frac{7}{16}$ | $2\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{8}$ | — | — | — | — | — | — | $7\frac{1}{2}$ |
| 24 | 12 | $10\frac{3}{8}$ | $6\frac{1}{4}$ | 12 | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $1\frac{7}{8}$ | $3\frac{1}{8}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $4\frac{5}{8}$ | $\frac{1}{2}$ | $3\frac{1}{8}$ | $\frac{5}{8}$ | 1 | $\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{8}$ | $6\frac{3}{8}$ | 1 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $8\frac{1}{2}$ |
| 28 | 14 | 12 | $7\frac{1}{4}$ | $13\frac{1}{2}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | $2\frac{1}{8}$ | $3\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 5 | $\frac{9}{16}$ | $3\frac{3}{8}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $7\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $\frac{5}{8}$ | $9\frac{1}{4}$ |
| 32 | 16 | $13\frac{5}{8}$ | 8 | 15 | 3 | 4 | $2\frac{1}{4}$ | $3\frac{7}{8}$ | $\frac{7}{8}$ | $1\frac{5}{8}$ | 2 | $5\frac{3}{4}$ | $\frac{5}{8}$ | $3\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{3}{8}$ | 8 | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $\frac{3}{4}$ | $10\frac{1}{2}$ |
| 36 | 18 | $14\frac{3}{4}$ | $8\frac{3}{4}$ | 17 | $3\frac{3}{8}$ | $4\frac{3}{8}$ | $2\frac{1}{2}$ | $4\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $6\frac{1}{8}$ | $\frac{11}{16}$ | $4\frac{1}{8}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $8\frac{3}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $\frac{3}{4}$ | $11\frac{1}{2}$ |
| 40 | 20 | $16\frac{3}{8}$ | $9\frac{1}{2}$ | 19 | $3\frac{3}{4}$ | $4\frac{3}{4}$ | $2\frac{5}{8}$ | $4\frac{5}{8}$ | $1\frac{1}{4}$ | 2 | $2\frac{1}{4}$ | $6\frac{5}{8}$ | $\frac{3}{4}$ | $4\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $9\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{7}{8}$ | $12\frac{1}{2}$ |
| 44 | 22 | $21\frac{5}{8}$ | 10 | 21 | 4 | $5\frac{1}{4}$ | $3\frac{1}{8}$ | 5 | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $2\frac{5}{8}$ | $7\frac{3}{8}$ | $\frac{13}{16}$ | $4\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{5}{8}$ | $1\frac{7}{8}$ | 10 | 2 | $2\frac{5}{8}$ | $\frac{7}{8}$ | 14 |

All Dimensions are given in Inches.




Figs. 264 and 265.

TABLE 23.—**Dimensions of Cast Steel Crossheads with Cast-iron Slippers** (Figs. 264, 265).

| Engines. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* |
| 24 | 12 | 12 | $6\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | 1 | $\frac{3}{4}$ | 2 | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{1}{16}$ |
| 32 | 16 | 15 | 8 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $2\frac{3}{8}$ | $\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{1}{16}$ |
| 40 | 20 | 19 | $9\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | 3 | $\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{1}{8}$ |
| 48 | 24 | 23 | $11\frac{1}{4}$ | 1 | $\frac{7}{8}$ | $\frac{3}{4}$ | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $3\frac{5}{8}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{8}$ |
| 56 | 28 | 27 | $12\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | $\frac{7}{8}$ | 2 | $1\frac{5}{8}$ | 4 | $\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{5}{8}$ | $\frac{7}{8}$ | $1\frac{5}{8}$ | $\frac{1}{8}$ |
| 64 | 32 | 31 | $14\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | 1 | $2\frac{1}{4}$ | 2 | $4\frac{3}{4}$ | $\frac{3}{4}$ | 2 | $1\frac{7}{8}$ | 1 | $1\frac{7}{8}$ | $\frac{1}{8}$ |
| 72 | 36 | $34\frac{1}{2}$ | $17\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $2\frac{5}{8}$ | $2\frac{1}{4}$ | $5\frac{3}{8}$ | $\frac{7}{8}$ | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $2\frac{1}{8}$ | $\frac{3}{16}$ |
| 80 | 40 | $38\frac{1}{2}$ | 20 | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $2\frac{3}{4}$ | $2\frac{3}{8}$ | 6 | $\frac{7}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $2\frac{3}{8}$ | $\frac{3}{16}$ |

All Dimensions are given in Inches.

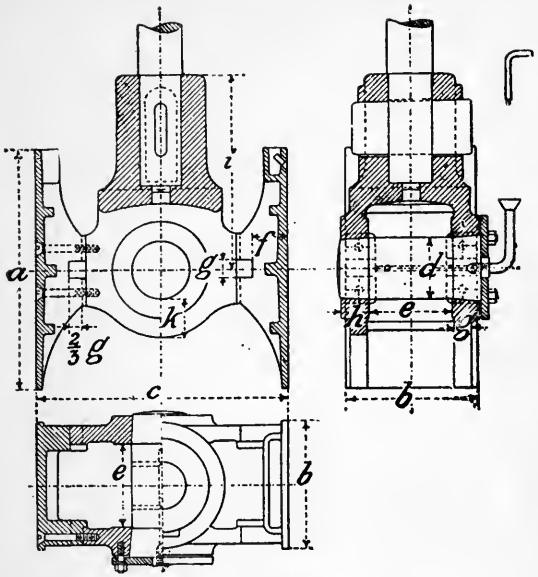



Fig. 266.

TABLE 24.—**Dimensions of Cast-steel Crossheads with Cast-iron Slippers** (Fig. 266).

| Engine. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* |
| 28 | 26 | 18 | 11 | 21 | $4\frac{1}{2}$ | $6\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{3}{8}$ | 2 | 15 | $2\frac{1}{2}$ |
| 30 | 28 | 20 | $11\frac{1}{2}$ | 22 | 5 | 7 | $2\frac{3}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{4}$ | 16 | $2\frac{3}{4}$ |
| 32 | 30 | 22 | 12 | 23 | $5\frac{1}{2}$ | $7\frac{1}{2}$ | 3 | $1\frac{5}{8}$ | $2\frac{1}{2}$ | 17 | 3 |
| 34 | 32 | 23 | $12\frac{1}{2}$ | 24 | $5\frac{3}{4}$ | 8 | $3\frac{1}{4}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | 18 | $3\frac{1}{4}$ |
| 36 | 34 | 24 | 13 | 25 | 6 | $8\frac{1}{2}$ | $3\frac{1}{2}$ | $1\frac{7}{8}$ | 3 | 19 | $3\frac{1}{2}$ |
| 38 | 36 | 25 | $13\frac{1}{2}$ | 26 | $6\frac{1}{4}$ | 9 | $3\frac{3}{4}$ | 2 | $3\frac{1}{4}$ | 20 | $3\frac{3}{4}$ |
| 40 | 38 | 26 | 14 | 27 | $6\frac{1}{2}$ | $9\frac{1}{2}$ | 4 | $2\frac{1}{4}$ | $3\frac{1}{2}$ | 21 | 4 |
| 42 | 40 | 27 | 15 | 28 | $6\frac{3}{4}$ | 10 | $4\frac{1}{4}$ | $2\frac{1}{2}$ | $3\frac{3}{4}$ | 22 | $4\frac{1}{4}$ |
| 44 | 44 | 28 | 16 | 29 | 7 | $10\frac{1}{2}$ | $4\frac{1}{2}$ | $2\frac{3}{4}$ | 4 | 23 | $4\frac{1}{2}$ |

All Dimensions are given in Inches.

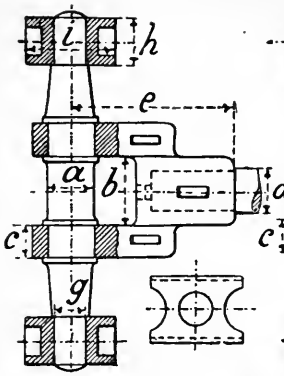



Fig. 267.

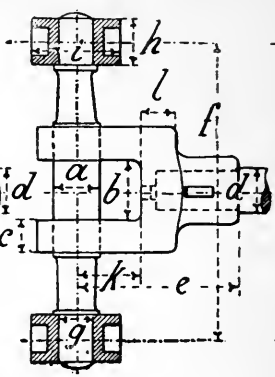


Fig. 268.

TABLE 25.—**Dimensions of Crossheads** (Figs. 267, 268) **for Bed-plate Engines,** page 19.

| Engines. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *d* | *a* | *b* | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* |
| 12 | 6 | $1\frac{3}{4}$ | $2\frac{1}{8}$ | 3 | $1\frac{1}{2}$ | 8 | 14 | $1\frac{1}{4}$ | 2 | $3\frac{1}{2}$ | 3 | $1\frac{1}{4}$ | $4\frac{1}{4}$ |
| 16 | 8 | 2 | $2\frac{3}{8}$ | $3\frac{1}{4}$ | $1\frac{3}{4}$ | 9 | 16 | $1\frac{1}{2}$ | $2\frac{3}{8}$ | $4\frac{3}{4}$ | $3\frac{3}{8}$ | $1\frac{1}{2}$ | $4\frac{3}{4}$ |
| 20 | 10 | $2\frac{1}{4}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | 2 | 10 | $19\frac{1}{2}$ | $1\frac{3}{4}$ | 3 | 6 | $3\frac{3}{4}$ | $1\frac{3}{4}$ | $5\frac{1}{4}$ |
| 24 | 12 | $2\frac{5}{8}$ | 3 | 4 | $2\frac{1}{4}$ | 11 | $21\frac{1}{2}$ | 2 | $3\frac{5}{8}$ | $7\frac{1}{4}$ | 4 | $2\frac{1}{8}$ | $5\frac{5}{8}$ |
| 28 | 14 | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $4\frac{1}{4}$ | $2\frac{3}{8}$ | 12 | 24 | $2\frac{1}{4}$ | $4\frac{5}{8}$ | $8\frac{3}{8}$ | $4\frac{1}{4}$ | $2\frac{1}{4}$ | $6\frac{3}{8}$ |
| 32 | 16 | 3 | $3\frac{5}{8}$ | $4\frac{5}{8}$ | $2\frac{5}{8}$ | 13 | 26 | $2\frac{3}{8}$ | $5\frac{1}{4}$ | $9\frac{1}{2}$ | $4\frac{5}{8}$ | $2\frac{3}{8}$ | 7 |
| 36 | 18 | $3\frac{1}{4}$ | 4 | 5 | $2\frac{3}{4}$ | 14 | 28 | $2\frac{5}{8}$ | 6 | $10\frac{3}{4}$ | 5 | $2\frac{5}{8}$ | $7\frac{5}{8}$ |
| 40 | 20 | $3\frac{5}{8}$ | $4\frac{3}{8}$ | $5\frac{1}{4}$ | 3 | 15 | 30 | $2\frac{3}{4}$ | $6\frac{3}{4}$ | 12 | $5\frac{3}{8}$ | $2\frac{7}{8}$ | $8\frac{3}{8}$ |
| 48 | 24 | $4\frac{3}{8}$ | $5\frac{3}{8}$ | $6\frac{3}{8}$ | $3\frac{3}{8}$ | 19 | 32 | $3\frac{3}{8}$ | $7\frac{5}{8}$ | $13\frac{5}{8}$ | $6\frac{3}{8}$ | $3\frac{1}{2}$ | 10 |
| 56 | 28 | $5\frac{1}{4}$ | $6\frac{3}{8}$ | $7\frac{5}{8}$ | $3\frac{3}{4}$ | 23 | 36 | 4 | $8\frac{3}{8}$ | $15\frac{1}{4}$ | $7\frac{3}{8}$ | $4\frac{1}{8}$ | $12\frac{3}{8}$ |
| 64 | 32 | 6 | $7\frac{3}{8}$ | $8\frac{3}{4}$ | $4\frac{3}{8}$ | 26 | 42 | $4\frac{5}{8}$ | $9\frac{5}{8}$ | $16\frac{3}{4}$ | $8\frac{3}{8}$ | $4\frac{3}{4}$ | $14\frac{3}{4}$ |
| 72 | 36 | 7 | $8\frac{3}{8}$ | 10 | 5 | 30 | 52 | $5\frac{1}{4}$ | $10\frac{3}{4}$ | $18\frac{3}{8}$ | $9\frac{3}{8}$ | $5\frac{1}{2}$ | $17\frac{1}{4}$ |
| 80 | 40 | 8 | $9\frac{5}{8}$ | $11\frac{1}{4}$ | $5\frac{1}{2}$ | 34 | 60 | 6 | 12 | 20 | $10\frac{5}{8}$ | $6\frac{3}{8}$ | 20 |

All Dimensions are given in Inches.

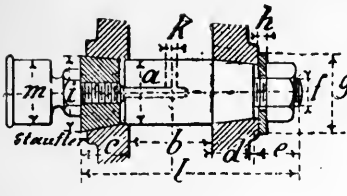



Fig. 269.

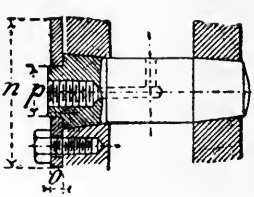



Fig. 270.

The above figs. show two methods of fixing crosshead pins, another method is shown on page 66, fig. 226, under connecting rods with remarks on different ways of fixing pins.

TABLE 26.—**Dimensions of Crosshead Pins** (Figs. 269, 270).

| Engines. | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* |
| 12 | 6 | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | 1 | $1\frac{1}{4}$ | $\frac{5}{8}$ | 2 | $\frac{3}{16}$ | $1\frac{5}{8}$ | $\frac{1}{4}$ | $5\frac{1}{4}$ | $\frac{3}{4}$ | — | – | — |
| 16 | 8 | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{3}{16}$ | $1\frac{7}{8}$ | $\frac{1}{4}$ | $6\frac{1}{8}$ | $1\frac{1}{4}$ | — | – | — |
| 20 | 10 | 2 | $2\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{5}{8}$ | $\frac{3}{16}$ | $2\frac{3}{8}$ | $\frac{1}{4}$ | $7\frac{3}{8}$ | $1\frac{1}{4}$ | — | – | — |
| 24 | 12 | $2\frac{1}{4}$ | $3\frac{1}{4}$ | 2 | $1\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{7}{8}$ | 3 | $\frac{1}{4}$ | $2\frac{3}{4}$ | $\frac{5}{16}$ | $8\frac{1}{2}$ | $1\frac{1}{2}$ | 4 | $\frac{3}{8}$ | $1\frac{1}{2}$ |
| 28 | 14 | $2\frac{5}{8}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ | 2 | $1\frac{1}{2}$ | $\frac{7}{8}$ | $3\frac{3}{8}$ | $\frac{1}{4}$ | 3 | $\frac{5}{16}$ | $9\frac{3}{8}$ | $1\frac{1}{2}$ | $4\frac{5}{8}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ |
| 32 | 16 | 3 | 4 | $2\frac{3}{8}$ | $2\frac{1}{4}$ | $1\frac{3}{4}$ | 1 | $3\frac{3}{4}$ | $\frac{5}{16}$ | $3\frac{1}{2}$ | $\frac{5}{16}$ | $10\frac{3}{8}$ | 2 | $5\frac{3}{8}$ | $\frac{5}{8}$ | 2 |
| 36 | 18 | $3\frac{3}{8}$ | $4\frac{3}{8}$ | $2\frac{3}{4}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | 1 | $4\frac{1}{4}$ | $\frac{3}{8}$ | 4 | $\frac{3}{8}$ | $11\frac{1}{2}$ | 2 | 6 | $\frac{5}{8}$ | $2\frac{1}{4}$ |
| 40 | 20 | $3\frac{3}{4}$ | $4\frac{3}{4}$ | $3\frac{1}{4}$ | $2\frac{3}{4}$ | 2 | $1\frac{1}{8}$ | $4\frac{5}{8}$ | $\frac{3}{8}$ | $4\frac{1}{4}$ | $\frac{3}{8}$ | $12\frac{3}{4}$ | $2\frac{3}{8}$ | $6\frac{3}{8}$ | $\frac{5}{8}$ | $2\frac{3}{8}$ |
| 44 | 22 | 4 | $5\frac{1}{4}$ | $3\frac{5}{8}$ | $3\frac{1}{4}$ | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $4\frac{3}{4}$ | $\frac{3}{8}$ | $4\frac{5}{8}$ | $\frac{3}{8}$ | $14\frac{1}{2}$ | $2\frac{3}{8}$ | $6\frac{3}{4}$ | $\frac{3}{4}$ | $2\frac{3}{4}$ |

All Dimensions are given in Inches.

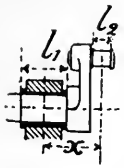



Fig. 271

The length of the main-bearing journal and the dimension $x$, depend in some measure on the design of the engine. In the Table $d$ = diameter, $l$ = length of journals and the upper figures are for 110, and the lower for 90 lbs. working pressure.

TABLE 27.—**Dimensions of Main Bearings, Crank Pins, and Crosshead Pins.**

| Diam. of Cylinder. | Main Bearing. | | Crank Pin. | | Crosshead Pin. | | Dimension of $x$. |
|---|---|---|---|---|---|---|---|
| D | $d_1$ | $l_1$ | $d_2$ | $l_2$ | $d_3$ | $l_3$ | $x=0{\cdot}9\,(l_1+l_2)$ |
| 10 | $4\frac{1}{2}$ | $7\frac{1}{4}$ | $2\frac{5}{8}$ | $3\frac{1}{4}$ | 2 | $2\frac{3}{4}$ | $9\frac{1}{4}$ |
| | 4 | $7\frac{1}{4}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | 2 | $2\frac{3}{4}$ | |
| 12 | $5\frac{1}{4}$ | $8\frac{1}{2}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $10\frac{3}{4}$ |
| | $4\frac{5}{8}$ | $8\frac{1}{2}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | |
| 14 | $6\frac{3}{8}$ | $9\frac{1}{2}$ | $3\frac{1}{4}$ | $4\frac{1}{4}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | $12\frac{1}{4}$ |
| | $5\frac{1}{4}$ | $9\frac{1}{2}$ | 3 | $4\frac{1}{4}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ | |
| 16 | 7 | $10\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{5}{8}$ | 3 | 4 | 14 |
| | 6 | $10\frac{3}{4}$ | $3\frac{3}{8}$ | $4\frac{5}{8}$ | 3 | 4 | |
| 18 | $7\frac{5}{8}$ | 12 | $4\frac{1}{4}$ | $5\frac{1}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{8}$ | $15\frac{5}{8}$ |
| | $6\frac{3}{4}$ | 12 | $3\frac{3}{4}$ | $5\frac{1}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{8}$ | |
| 20 | $8\frac{3}{4}$ | $13\frac{1}{4}$ | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{3}{4}$ | $17\frac{1}{4}$ |
| | $7\frac{5}{8}$ | $13\frac{1}{4}$ | $4\frac{1}{4}$ | $5\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{3}{4}$ | |
| 22 | 10 | $14\frac{3}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | 4 | $5\frac{1}{4}$ | $18\frac{1}{2}$ |
| | $8\frac{3}{8}$ | $14\frac{3}{4}$ | $4\frac{5}{8}$ | $6\frac{3}{8}$ | 4 | $5\frac{1}{4}$ | |

All Dimensions are given in Inches.

TABLE 28.—**Dimensions of Piston Rods, Main Bearings, Crank Pins and Crosshead Pins for Engines with 90 to 110 lbs. Working Pressure.** (For Engine Frame, see page 30.)

| Engines. | | Revs. per Min. | Piston speed ft. per min. | Piston Rods. | Main Bearings. | | Crank Pins. | | Crosshead Pins. | |
|---|---|---|---|---|---|---|---|---|---|---|
| H | D | $n$ | $c$ | $d$ | $d$ | $l$ | $d$ | $l$ | $d$ | $l$ |
| 12 | 6 | 125 | 250 | $1\frac{1}{8}$ | — | — | — | — | $1\frac{3}{8}$ | $1\frac{3}{4}$ |
| 16 | 8 | 110 | 283 | $1\frac{3}{8}$ | — | — | — | — | $1\frac{1}{2}$ | $2\frac{1}{8}$ |
| 20 | 10 | 100 | 334 | $1\frac{5}{8}$ | $4\frac{1}{2}$ | $7\frac{1}{4}$ | $2\frac{5}{8}$ | $3\frac{1}{4}$ | 2 | $2\frac{3}{4}$ |
| 24 | 12 | 90 | 360 | 2 | $5\frac{1}{4}$ | $8\frac{1}{2}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ |
| 28 | 14 | 85 | 396 | $2\frac{1}{4}$ | $6\frac{3}{8}$ | $9\frac{1}{2}$ | $3\frac{1}{4}$ | $4\frac{1}{4}$ | $2\frac{5}{8}$ | $3\frac{5}{8}$ |
| 32 | 16 | 80 | 426 | $2\frac{3}{8}$ | 7 | $10\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{5}{8}$ | 3 | 4 |
| 36 | 18 | 78 | 468 | $2\frac{5}{8}$ | $7\frac{5}{8}$ | 12 | $4\frac{1}{4}$ | $5\frac{1}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{8}$ |
| 40 | 20 | 75 | 500 | $2\frac{3}{4}$ | $8\frac{3}{4}$ | $13\frac{1}{4}$ | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{3}{4}$ |
| 44 | 22 | 72 | 528 | $3\frac{1}{4}$ | 10 | $14\frac{3}{4}$ | $5\frac{1}{4}$ | $6\frac{3}{8}$ | 4 | $5\frac{1}{4}$ |
| 48 | 24 | 70 | 560 | $3\frac{3}{4}$ | $11\frac{1}{4}$ | $16\frac{3}{4}$ | $5\frac{3}{4}$ | $7\frac{1}{4}$ | 5 | $5\frac{3}{4}$ |
| 56 | 28 | 61 | 570 | $4\frac{3}{8}$ | $12\frac{1}{2}$ | $18\frac{3}{4}$ | $6\frac{1}{2}$ | 8 | $5\frac{3}{4}$ | $6\frac{3}{8}$ |
| 64 | 32 | $54\frac{1}{2}$ | 580 | $5\frac{1}{4}$ | 14 | $21\frac{1}{4}$ | $7\frac{3}{4}$ | $9\frac{1}{4}$ | $6\frac{1}{2}$ | $7\frac{1}{4}$ |
| 72 | 36 | 49 | 590 | 6 | $15\frac{3}{4}$ | 24 | $8\frac{3}{4}$ | $10\frac{3}{8}$ | $7\frac{1}{4}$ | 8 |
| 80 | 40 | 45 | 600 | $6\frac{3}{4}$ | $17\frac{1}{4}$ | 26 | $9\frac{1}{2}$ | $11\frac{5}{8}$ | 8 | $9\frac{1}{4}$ |
| 88 | 44 | 41 | 600 | $7\frac{5}{8}$ | $18\frac{3}{4}$ | $28\frac{3}{4}$ | $10\frac{1}{2}$ | $13\frac{1}{4}$ | $8\frac{3}{4}$ | $10\frac{3}{8}$ |

All Dimensions are given in Inches, except those in Column $a$.

## Piston Rods.

Piston rods are now almost always made of either Bessemer or open-hearth steel

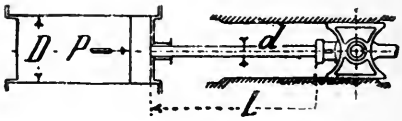



Fig. 272.

Both ends of the piston rod can be taken as fixed, then the diameter to resist crushing may be taken from the formula $d = \cdot 0324 \sqrt[4]{P L^2}$ where $d$ = diameter of rod in inches, P the maximum pressure on the piston in lbs., and L the length of the rod. A more direct method of determining the diameter of the piston rod is in proportion to the area of the piston and the maximum pressure thereon.

Thus if A = area of piston and $a$ = area of piston rod, then for a maximum boiler pressure of 80 lbs. $\frac{A}{41} = a$ or $A \times \cdot 0244 = a$ gives a very safe strength for the smallest part of the rod, usually that part of the rod around the cottar hole at crosshead end, and as the rod has to be of a somewhat larger diameter in that part which passes through the cylinder cover, there is ample strength to resist crushing or bending.

Another way is to give sufficient metal in the smallest area of the rod to give a maximum stress of $1\frac{3}{4}$ tons per square inch, in some cases the stress may be as high as 2 tons per square inch. The staff or main part of the rod is often made about $\frac{1}{16}$" to $\frac{1}{8}$" larger than the largest diameter where it enters the crosshead, thus giving a small shoulder, this is for allowing the rod to be trued up after wear, without disturbing the part which fits into the crosshead.

## Pistons.

Of pistons for steam engines there are endless varieties, high speeds and high pressures rendering it difficult to construct a perfect piston, and in fact this difficulty is well shown by the number of new pistons that are constantly being advertised in the technical journals. A

perfect piston should work silently, and keep steam tight for a reasonable length of time, and should be as near frictionless as possible; the number of parts should be few, and all bolts and nuts secured from working loose. The attachment of the piston to the rod is a matter of great importance, the cone and nut shown in figs. 273, 276 has been successfully used on small pistons, but it is questionable whether a parallel rod with collar and nut is not better for very large pistons, accidents having happened from the piston body being burst by gradually mounting up the cone, especially when the taper of the latter has been too slight; a good proportion for the cone is a taper of $1\frac{1}{2}$ inches of diameter to one foot of length.

Figs. 273, 274 show a form of plain piston fitted with Ramsbottom rings, figs. 275, 276, 277, a good and cheap form for small pistons with one inside and two outside rings, all of cast iron, fig. 284, a spiral coil-spring piston of cast iron, with cast-iron outside rings.

Fig. 273. Fig. 274. Fig. 275.

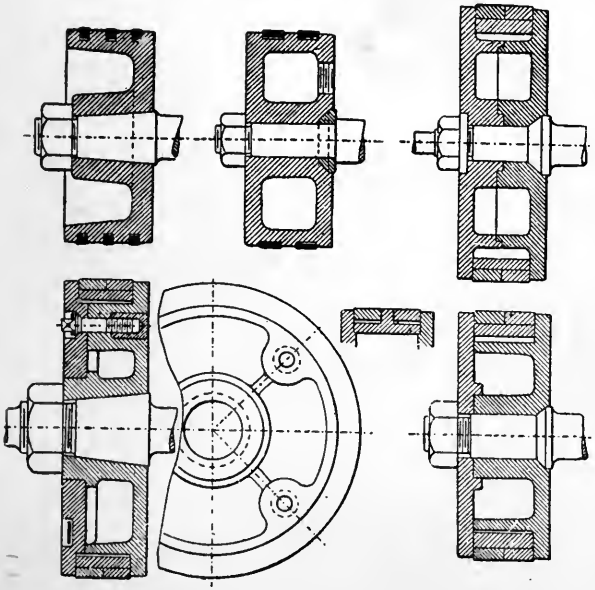


Fig. 276. Fig. 277.

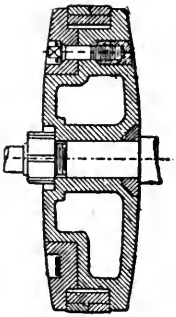


Fig. 278.

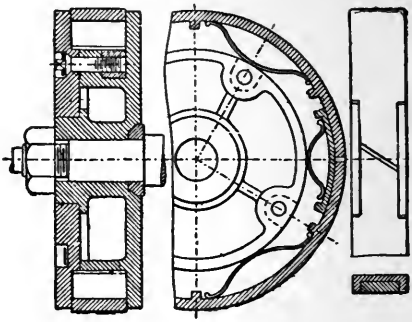


Fig. 279.

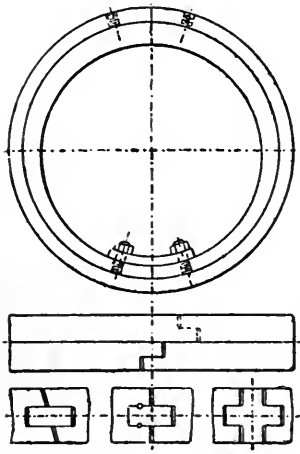


Fig. 280.

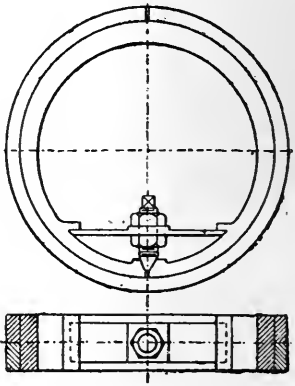


Fig. 281.

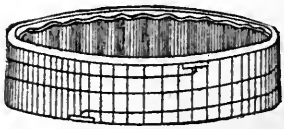


Fig. 282.—Cremer's Piston with spiral ring.

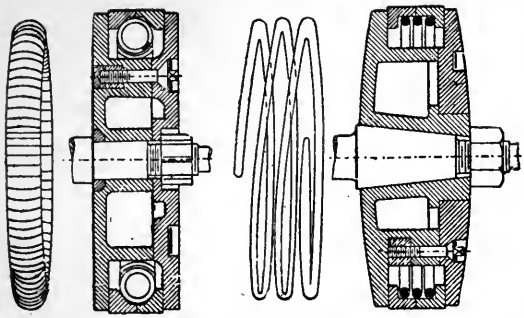


Fig. 283. Fig. 284.

Fig. 284.—A Piston with helical spring bearing on outside cast-iron rings

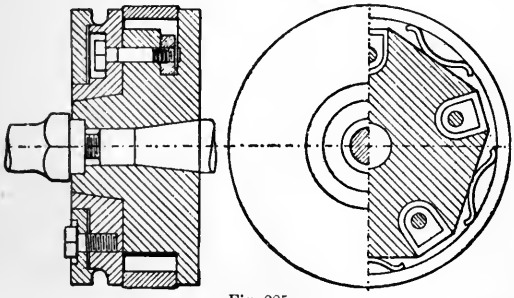


Fig. 285.

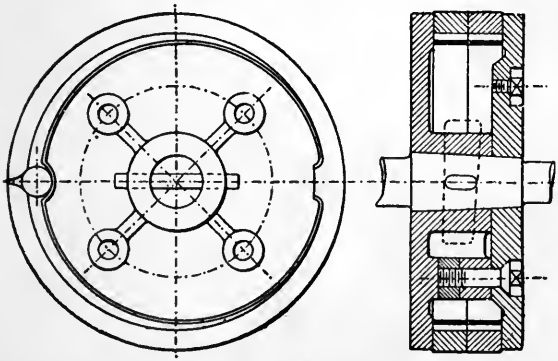


Fig. 286

Fig. 286.—Piston with two outside cast-iron rings and steel spring ring, with block at joint. This is a cheap form derived from an older form of locomotive piston, and has been much used for portable engines.

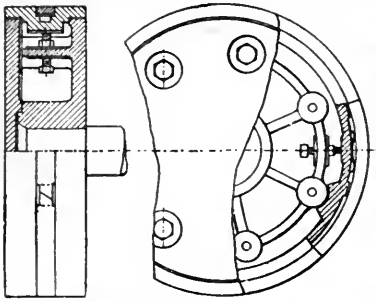


Fig. 287.

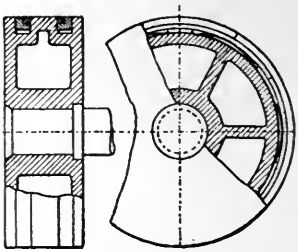
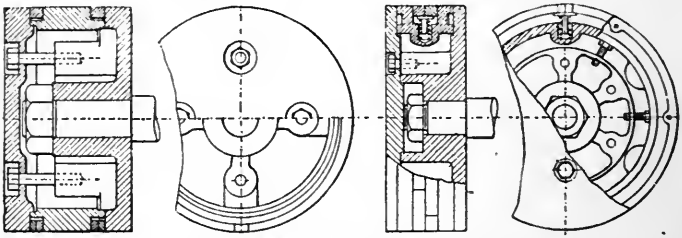


Fig. 288.



Figs. 289 and 290.—American Pistons.

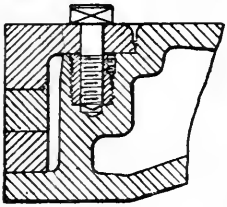


Fig. 291.

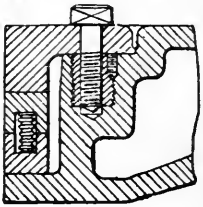


Fig. 292.

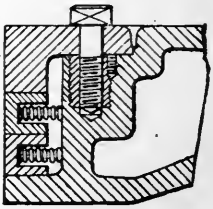


Fig. 293.

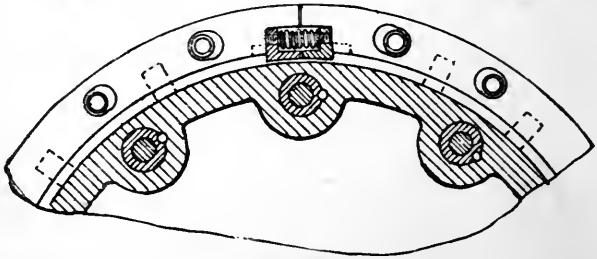


Fig. 294.

Figs. 291 to 208.—Marine Pistons.

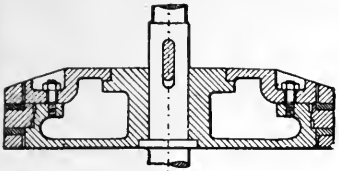


Fig. 295.

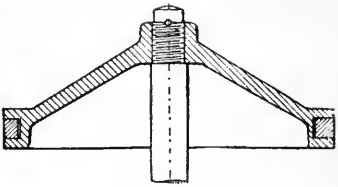


Fig. 296.

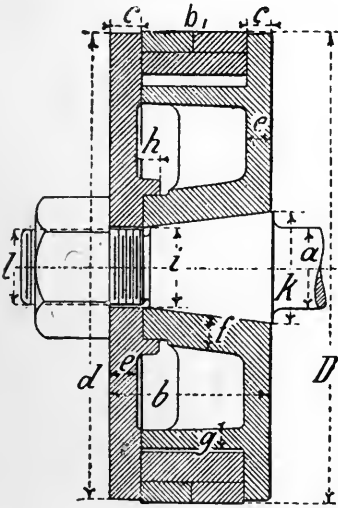



Fig. 297.

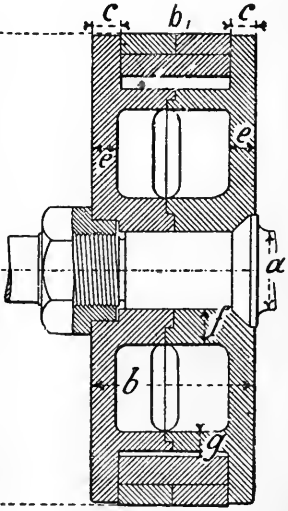



Fig. 298.

TABLE 29.—**Dimensions of Pistons from 6″ to 16″ Diameter, with Cover held on by Piston-rod Nut** (Figs. 297, 298.)

| D | *a* | *b* | $b_1$ | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | $1\frac{1}{8}$ | 3 | 2 | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | 1 |
| 8 | $1\frac{3}{8}$ | $3\frac{1}{4}$ | $2\frac{1}{8}$ | $\frac{9}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{5}{16}$ | $1\frac{3}{8}$ | 2 | $1\frac{1}{4}$ |
| 10 | $1\frac{5}{8}$ | $3\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{9}{16}$ | $\frac{11}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $1\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{2}$ |
| 12 | 2 | 4 | $2\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{3}{4}$ | $1\frac{7}{8}$ |
| 14 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | 3 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{13}{16}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{1}{8}$ | $3\frac{1}{4}$ | 2 |
| 16 | $2\frac{3}{8}$ | $4\frac{3}{4}$ | $3\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $2\frac{5}{16}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ |

Fig 303.

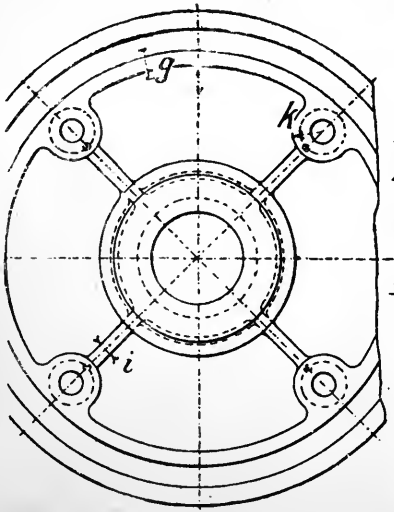



Fig. 300.

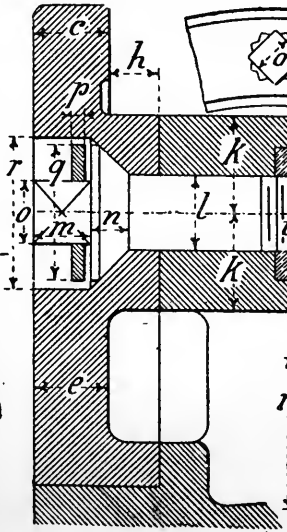



Fig. 299.

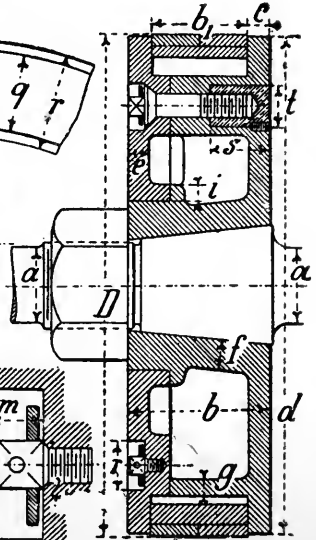



Fig. 302.

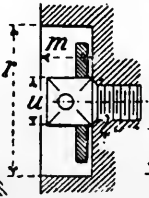
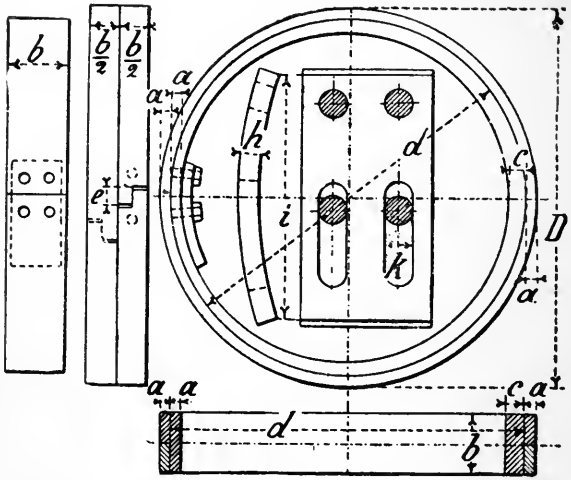



Fig. 301.

TABLE 30.—**Dimensions of Pistons with Cover held on by Bolts. From 14″ up to 40″ Diameter** (Fig. 299).

| | NOTE.—All Dimensions are in Inches. | | | | | | | | | | Cover bolts. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D | $a$ | $b$ | $b_1$ | $c$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | No. | $l$ | $m$ | $n$ | $o$ | $p$ | $q$ | $r$ | $s$ | $t$ | $u$ |
| 14 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | 3 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | 1 | 4 | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{7}{16}$ | $\frac{5}{8}$ | $\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | 2 | $1\frac{3}{8}$ | $\frac{1}{2}$ |
| 16 | $2\frac{3}{8}$ | $4\frac{3}{4}$ | $3\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 1 | 5 | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{7}{16}$ | $\frac{5}{8}$ | $\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | 2 | $1\frac{3}{8}$ | $\frac{1}{2}$ |
| 18 | $2\frac{5}{8}$ | 5 | $3\frac{3}{8}$ | $\frac{13}{16}$ | $\frac{11}{16}$ | 1 | $\frac{9}{16}$ | $\frac{9}{16}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | 5 | $\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ |
| 20 | $2\frac{3}{4}$ | $5\frac{1}{4}$ | $3\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | 1 | $\frac{5}{8}$ | $\frac{9}{16}$ | $\frac{9}{16}$ | $1\frac{1}{4}$ | 5 | $\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ |
| 22 | $3\frac{1}{4}$ | $5\frac{1}{2}$ | $3\frac{5}{8}$ | $\frac{15}{16}$ | $\frac{3}{4}$ | 1 | $\frac{5}{8}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | 6 | $\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ |
| 24 | $3\frac{3}{4}$ | 6 | 4 | 1 | $\frac{13}{16}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | 6 | 1 | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{16}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ |
| 28 | $4\frac{3}{8}$ | $6\frac{3}{4}$ | $4\frac{3}{4}$ | 1 | $\frac{7}{8}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | 7 | 1 | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{16}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ |
| 32 | $5\frac{1}{4}$ | $7\frac{3}{4}$ | $5\frac{1}{4}$ | $1\frac{1}{4}$ | 1 | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{2}$ | 7 | $1\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | 1 | $\frac{3}{16}$ | $2\frac{1}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | 2 | $\frac{3}{4}$ |
| 36 | 6 | $8\frac{3}{8}$ | $5\frac{7}{8}$ | $1\frac{1}{4}$ | 1 | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | $1\frac{1}{2}$ | 8 | $1\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | 1 | $\frac{3}{16}$ | $2\frac{1}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | 2 | $\frac{3}{4}$ |
| 40 | $6\frac{3}{4}$ | $8\frac{3}{4}$ | 6 | $1\frac{3}{8}$ | $1\frac{1}{16}$ | 2 | 1 | 1 | 1 | $1\frac{5}{8}$ | 8 | $1\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | 1 | $\frac{1}{4}$ | $2\frac{1}{4}$ | $2\frac{1}{2}$ | 3 | $2\frac{1}{8}$ | $\frac{3}{4}$ |

Fig. 306.




Figs. 308 and 307. Fig. 305.

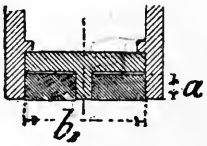



Fig. 304.

Figures 304 to 308 show an ordinary set of piston rings with tongue piece on inside ring, and the outside ring cut so as to prevent marking the cylinder and also to prevent the leakage of steam. This way of cutting the rings is not usually considered necessary, a diagonal cut being generally sufficient with or without the tongue pieces. Table 31 gives the dimensions of these rings.

TABLE 31.—**Dimensions of Piston Rings** (Figs. 304 to 308).

| D | $b$ | $a$ | $c$ | $D_1$ | $f$ | $e$ | D | $d$ | $d_1$ | $g$ | $d$ | $h$ | $i$ | $k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | $1\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{1}{2}$ | $4\frac{1}{4}$ | — | $\frac{3}{8}$ | 4 | $3\frac{3}{8}$ | $3\frac{7}{16}$ | — | $3\frac{3}{8}$ | $\frac{1}{4}$ | 2 | $\frac{5}{16}$ |
| 6 | 2 | $\frac{5}{16}$ | $\frac{9}{16}$ | $6\frac{1}{4}$ | — | $\frac{1}{2}$ | 6 | $5\frac{3}{8}$ | $5\frac{7}{16}$ | $\frac{1}{16}$ | $5\frac{3}{8}$ | $\frac{1}{4}$ | $2\frac{3}{8}$ | $\frac{5}{16}$ |
| 8 | $2\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | $8\frac{5}{16}$ | — | $\frac{5}{8}$ | 8 | $7\frac{1}{4}$ | $7\frac{5}{16}$ | $\frac{1}{8}$ | $7\frac{1}{4}$ | $\frac{1}{4}$ | $2\frac{3}{4}$ | $\frac{5}{16}$ |
| 10 | $2\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | $10\frac{3}{8}$ | $\frac{3}{16}$ | $\frac{5}{8}$ | 10 | $9\frac{1}{4}$ | $9\frac{3}{8}$ | $\frac{3}{16}$ | $9\frac{1}{4}$ | $\frac{5}{16}$ | $3\frac{1}{4}$ | $\frac{3}{8}$ |
| 12 | $2\frac{5}{8}$ | $\frac{7}{16}$ | $\frac{3}{4}$ | $12\frac{7}{16}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | 12 | $11\frac{1}{8}$ | $11\frac{1}{4}$ | $\frac{3}{16}$ | $11\frac{1}{8}$ | $\frac{5}{16}$ | $3\frac{5}{8}$ | $\frac{3}{8}$ |
| 14 | 3 | $\frac{1}{2}$ | $\frac{3}{4}$ | $14\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | 14 | 13 | $13\frac{5}{16}$ | $\frac{1}{4}$ | 13 | $\frac{3}{8}$ | 4 | $\frac{3}{8}$ |
| 16 | $3\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{13}{16}$ | $16\frac{9}{16}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 16 | 15 | $15\frac{1}{4}$ | $\frac{3}{8}$ | 15 | $\frac{3}{8}$ | $4\frac{3}{8}$ | $\frac{1}{2}$ |
| 18 | $3\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $18\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 18 | $16\frac{3}{4}$ | 16 | $\frac{1}{2}$ | $16\frac{3}{4}$ | $\frac{1}{2}$ | $4\frac{3}{4}$ | $\frac{1}{2}$ |
| 20 | $3\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $20\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 20 | $18\frac{3}{4}$ | $19\frac{1}{4}$ | $\frac{5}{8}$ | $18\frac{3}{4}$ | $\frac{1}{2}$ | $5\frac{1}{4}$ | $\frac{1}{2}$ |
| 22 | $3\frac{5}{8}$ | $\frac{11}{16}$ | 1 | $22\frac{11}{16}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 22 | $20\frac{5}{8}$ | 21 | $\frac{3}{4}$ | $20\frac{5}{8}$ | $\frac{1}{2}$ | $5\frac{5}{8}$ | $\frac{1}{2}$ |
| 24 | 4 | $\frac{11}{16}$ | 1 | $24\frac{3}{4}$ | $\frac{7}{8}$ | 1 | 24 | $22\frac{5}{8}$ | 23 | 1 | $22\frac{5}{8}$ | $\frac{1}{2}$ | 6 | $\frac{5}{8}$ |
| 28 | $4\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{8}$ | $28\frac{7}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{16}$ | 28 | $26\frac{1}{2}$ | 27 | $1\frac{1}{4}$ | $26\frac{1}{2}$ | $\frac{1}{2}$ | $6\frac{3}{8}$ | $\frac{5}{8}$ |
| 32 | $5\frac{1}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | 33 | $1\frac{1}{4}$ | $1\frac{1}{4}$ | 32 | $30\frac{1}{2}$ | 31 | $1\frac{3}{8}$ | $30\frac{1}{2}$ | $\frac{9}{16}$ | $6\frac{3}{4}$ | $\frac{5}{8}$ |
| 36 | $5\frac{7}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | 37 | $1\frac{3}{8}$ | $1\frac{1}{2}$ | 36 | $34\frac{1}{4}$ | $34\frac{7}{8}$ | $1\frac{1}{2}$ | $34\frac{1}{4}$ | $\frac{5}{8}$ | $7\frac{1}{4}$ | $\frac{5}{8}$ |
| 40 | 6 | $\frac{7}{8}$ | $1\frac{3}{8}$ | $41\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | 40 | $38\frac{1}{4}$ | 39 | $1\frac{7}{8}$ | $38\frac{1}{4}$ | $\frac{5}{8}$ | $7\frac{5}{8}$ | $\frac{5}{8}$ |

All Dimensions are given in Inches.

## Piston Rods.

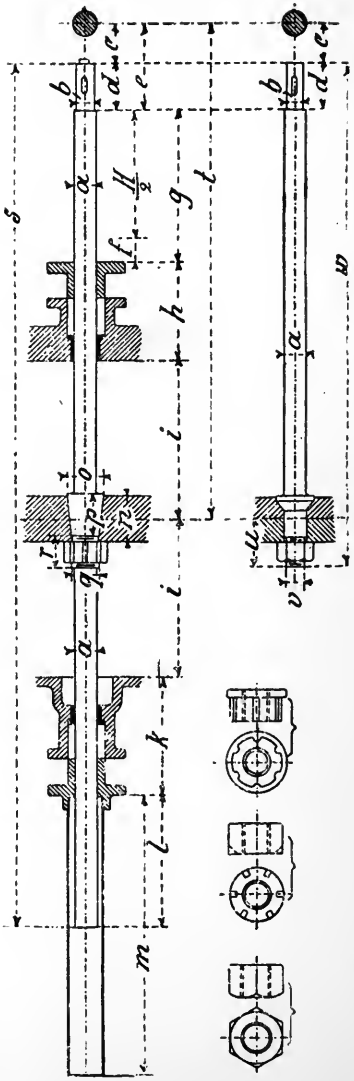



Fig. 309.

Fig. 313.

Figs. 310—312

TABLE 32.—**Dimensions of Piston Rods** (Figs. 309, 313).

| Engine. | | NOTE.—All Dimensions are given in Inches. | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* |
| 12 | 6 | $1\frac{1}{8}$ | 1 | $2\frac{1}{2}$ | $2\frac{3}{4}$ | $5\frac{1}{4}$ | $1\frac{1}{16}$ | $7\frac{1}{16}$ | 7 | $7\frac{11}{16}$ | — | — | — | 3 | — | $2\frac{3}{4}$ | — | — | — | 27 | $2\frac{3}{4}$ | $1\frac{1}{8}$ | $27\frac{1}{4}$ |
| 16 | 8 | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $2\frac{7}{8}$ | $3\frac{5}{8}$ | $6\frac{1}{2}$ | $1\frac{1}{16}$ | $9\frac{1}{16}$ | $8\frac{1}{4}$ | $9\frac{13}{16}$ | — | — | — | $3\frac{1}{4}$ | — | 3 | — | — | — | $33\frac{5}{8}$ | $3\frac{1}{4}$ | $1\frac{3}{8}$ | 34 |
| 20 | 10 | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $3\frac{3}{8}$ | $4\frac{1}{8}$ | $7\frac{1}{2}$ | $1\frac{1}{16}$ | $11\frac{1}{8}$ | $9\frac{3}{8}$ | 12 | — | — | — | $3\frac{5}{8}$ | — | $3\frac{1}{2}$ | — | — | — | 40 | $3\frac{3}{4}$ | $1\frac{3}{4}$ | $40\frac{3}{8}$ |
| 24 | 12 | 2 | $1\frac{7}{8}$ | $3\frac{7}{8}$ | $4\frac{5}{8}$ | $8\frac{1}{2}$ | $1\frac{1}{16}$ | $13\frac{1}{16}$ | $10\frac{1}{2}$ | $14\frac{3}{16}$ | — | 12 | 28 | 4 | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | — | $46\frac{1}{4}$ | — | — | — |
| 28 | 14 | $2\frac{1}{4}$ | $2\frac{1}{8}$ | $4\frac{1}{4}$ | 5 | $9\frac{1}{4}$ | $1\frac{1}{8}$ | $15\frac{1}{8}$ | $11\frac{1}{8}$ | $16\frac{1}{2}$ | — | 14 | 32 | $4\frac{1}{2}$ | $3\frac{1}{2}$ | 4 | $2\frac{1}{2}$ | $2\frac{1}{2}$ | — | 52 | — | — | — |
| 32 | 16 | $2\frac{3}{8}$ | $2\frac{1}{4}$ | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $10\frac{1}{2}$ | $1\frac{3}{8}$ | $17\frac{3}{8}$ | $11\frac{1}{2}$ | $18\frac{7}{8}$ | — | 16 | 36 | $4\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | — | 58 | — | — | — |
| 36 | 18 | $2\frac{5}{8}$ | $2\frac{1}{2}$ | $5\frac{3}{8}$ | $6\frac{1}{8}$ | $11\frac{1}{2}$ | $1\frac{9}{16}$ | $19\frac{9}{16}$ | $12\frac{1}{8}$ | $20\frac{13}{16}$ | — | 18 | 40 | 5 | 4 | $4\frac{5}{8}$ | 3 | 3 | — | 64 | — | — | — |
| 40 | 20 | $2\frac{3}{4}$ | $2\frac{5}{8}$ | $5\frac{7}{8}$ | $6\frac{5}{8}$ | $12\frac{1}{2}$ | $1\frac{9}{16}$ | $21\frac{9}{16}$ | $12\frac{3}{4}$ | $22\frac{15}{16}$ | — | 20 | 44 | $5\frac{1}{4}$ | $4\frac{1}{2}$ | $4\frac{3}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | — | $69\frac{3}{4}$ | — | — | — |
| 44 | 22 | $3\frac{1}{4}$ | $3\frac{1}{8}$ | $6\frac{5}{8}$ | $7\frac{3}{8}$ | 14 | $1\frac{9}{16}$ | $23\frac{9}{16}$ | $14\frac{1}{8}$ | $25\frac{1}{16}$ | — | 22 | 48 | $5\frac{1}{2}$ | $4\frac{3}{4}$ | 5 | $3\frac{5}{8}$ | $3\frac{5}{8}$ | — | $76\frac{3}{4}$ | — | — | — |

## Steam Engine Cylinders.

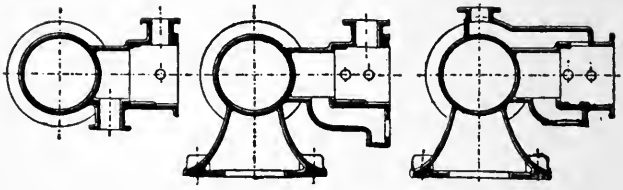


Fig. 314. Fig. 315. Fig. 316.

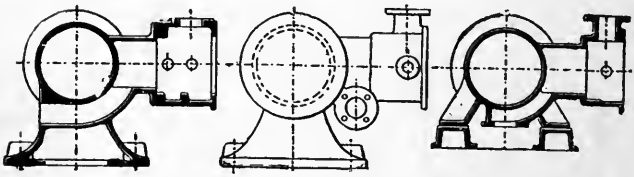


Fig. 317. Fig. 318. Fig. 319.

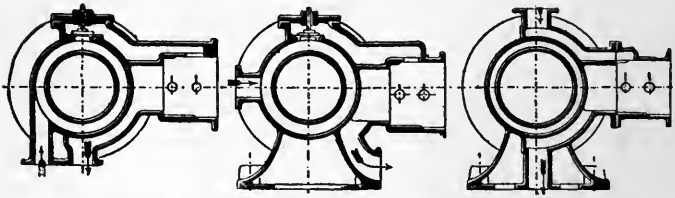


Fig. 320. Fig. 321. Fig. 322.

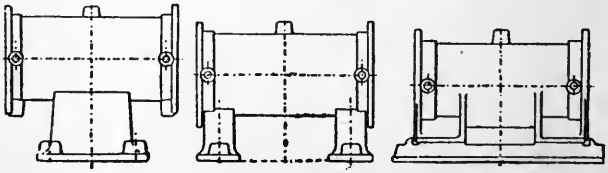
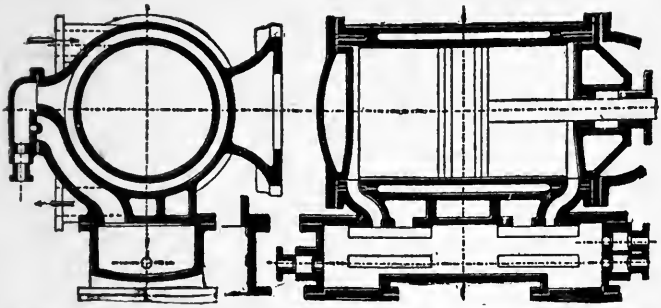
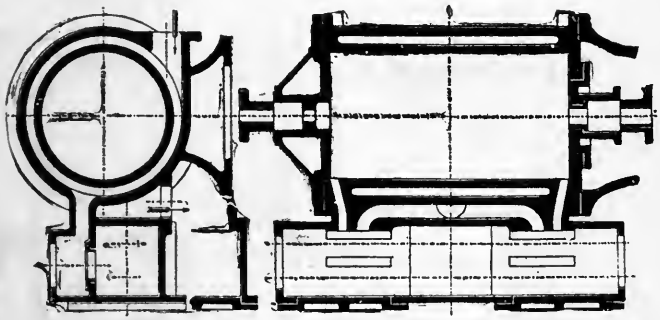


Fig. 323. Fig. 324. Fig. 325.

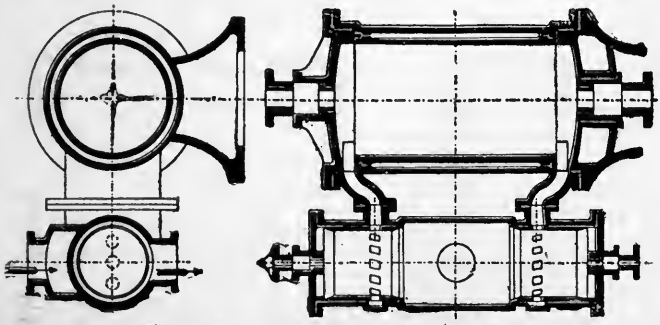
The above figures show different designs for cylinders of horizontal engines with and without steam jackets.



Figs. 327 and 328.—Cylinder for double slide valve gear, with the valves in two parts; an arrangement which reduces the length of the steam ports to the shortest length possible with slide valves



Figs. 329 and 330.—Cylinder for Rider's valve gear, with the valves in two parts to reduce length of steam ports.



Figs. 331 and 332.—Cylinder for piston slide valve.

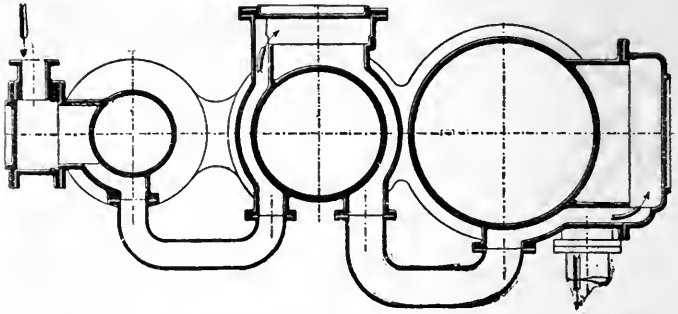
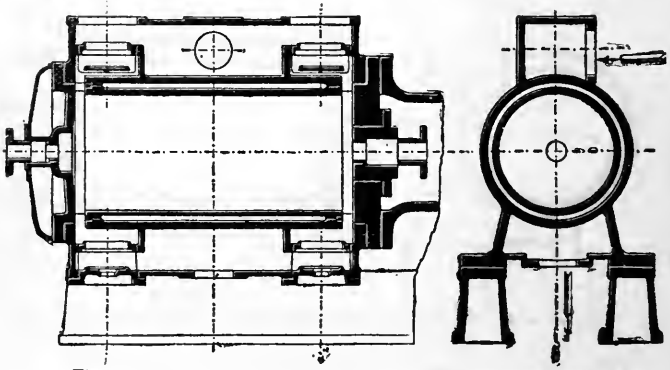
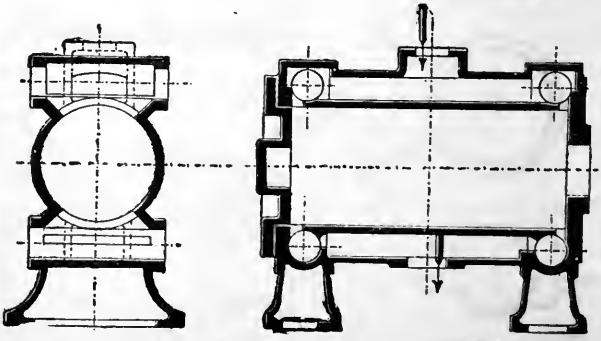


Fig. 333.—Cylinders for triple-expansion engine, designed for use with frame shown fig. 89, page 32. In this arrangement all the three slide valves are easy of access.



Figs. 334 and 335.—Cylinder for valve gear, with mushroom valves.



Figs. 336 and 337.—Cylinder for valve gear, with Corliss valves.

Fig. 338.

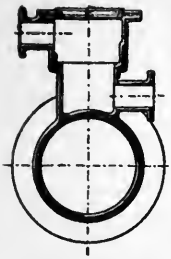
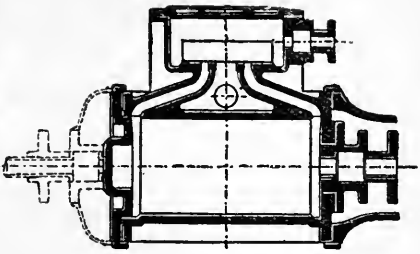
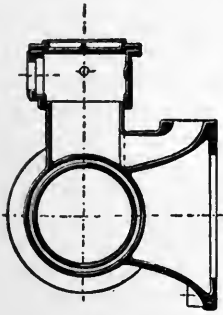


Fig. 339.





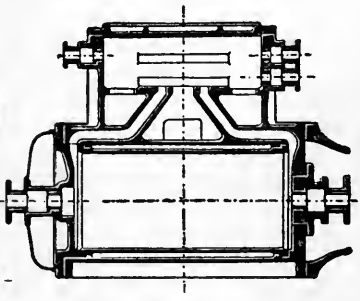
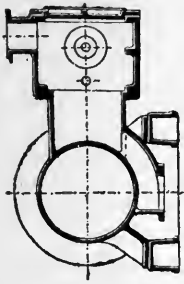


Fig. 340.

Fig. 341.



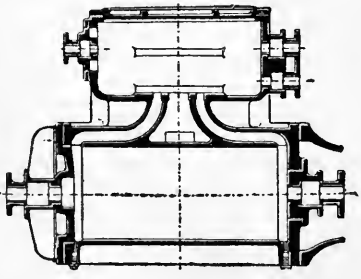


Fig. 342.

Fig. 343.

Figs. 338 and 339.—Cylinder for ordinary simple slide valve gear.
Figs. 340 and 341.—Cylinder for Meyer's slide valve gear.
Figs. 342 and 343.—Cylinder for Rider's valve gear.

In the above examples the slide valve chest is shown shorter than the cylinder; this arrangement saves weight, but it is often more convenient to make it the same length as the cylinder and to bolt the stuffing boxes on.

The thickness of the cylinder walls in small or medium sized engines has been determined from practice more than from calculation, and ranges from $\frac{5}{8}$" in small cylinders up to 9" bore; beyond that size an approximate formula is $t$ = thickness of walls in inches = ·75 + $\frac{D}{100}$, where D = bore of cylinder in inches; this formula gives the thickness rather high for small cylinders. The thickness of the cylinder covers has also been determined by practice and depends on the steam pressure and also on the construction of the cover, whether strengthened by ribs for the larger cylinders or plain for the smaller ones. The thickness of the cover at the bolt circle is often made a little less than that of the cylinder flange; the thickness of the flange being about 1·25 times the thickness of the cylinder walls. The bolts for holding the cover on must be spaced according to the load on the cover, the strain on the bolts being about 2 tons per square inch of section at bottom of thread; (see table 151, page 411, which gives the areas at bottom of thread of the usual sizes of bolts), but it should be remembered that bolts smaller than $\frac{5}{8}$" diameter may be overstrained by tightening up with an ordinary spanner and seriously injured before any pressure or working stress comes upon them.

The bosses on the ends of the cylinder for attachment of the Indicator cocks are tapped with $\frac{3}{4}$" Whitworth thread, and fitted with screw plugs often made of iron, but if not occasionally removed are apt to rust in and must be drilled out; they should therefore be of brass. The steam ports should be sufficiently large to admit the steam at a maximum velocity of 100 feet per second; as in some valve gears the port is not opened to its full width to steam, care should be taken in calculating the speed of the entering steam to reckon only for the opening of the port to steam up to the edge of the valve. If the steam is cut off early when the engine is running on full load it is obvious that the ports need not be so large as for the later cut off, as the piston speed is naturally less near the beginning than towards the middle of the stroke.

The length of the port, *i.e.* the dimension measured at right angles to the length of the cylinder, depends on the design of the cylinder, and this being determined, the other dimension is readily calculated from the area.

In cylinder construction it is important to arrange bosses for connection of all pipes required, and specially to arrange for efficient means of draining and lubricating the cylinder barrel, for admitting steam to the jacket and draining the same in an efficient

manner. Other important points are the means for neatly clothing the cylinder with some non-conducting medium.

It may be again mentioned here that in order to save multiplications of patterns, the cylinder as well as other parts of engines should be designed symmetrically about their centre lines, so that a cylinder by being turned end for end may be used for either a right or a left hand engine.

**Clearance space in Steam Engine Cylinders.**—A small distance between the piston at each end of the stroke and the cylinder covers is necessary in order to prevent the piston from coming into contact with the covers. This space, called "clearance," should be as small as possible, but cannot be reduced beyond a certain limit, as the length of the connecting rod alters by wear and adjustment; therefore the clearance is seldom less than $\frac{5}{16}$" in small engines and somewhat more in larger engines. In calculating the amount of steam used in an engine this space has to be added to the volume swept by the piston in its stroke; in addition to the clearance space at the end of the stroke, there are the steam passages, and if a double slide valve gear, the hollow part of the main valve to be taken in. Fig. 344 shows the clearance space and steam passage shaded at the left hand end of the cylinder. In this case it amounts to 450 cubic inches, the volume swept by the piston equals 7320 cubic inches $\frac{450 \times 100}{7320} = 6{\cdot}1$ per cent., so the clearance space amounts to 6·1 per cent. of the volume of the stroke. Table 33 shows the clearance spaces for different varieties of ports.

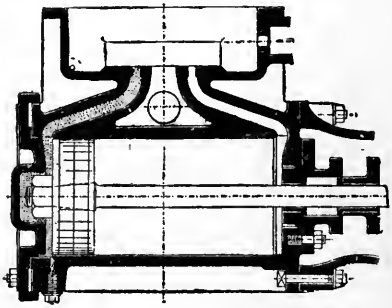
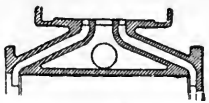
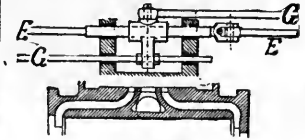


Fig. 344.

TABLE 33.—**Percentage of Clearance Space with Steam Ports of different Design.**

| Engine. | For the Normal Velocity of the Steam. |  Fig. 345. |   Fig. 346. | Fig. 347. |
|---|---|---|---|---|
| D=10 | Steam port . | 52·5 | 45·5 | 23·5 |
| | Clearance . . | 16·2 | 16·2 | 16·2 |
| H=16 | Recess in cover . | 8·6 | 8·6 | 8·6 |
| | Recess in cover . | 1·5 | 1·5 | 1·5 |
| $n$=120 | Ring in cylinder | 3·4 | 3·4 | 3·4 |
| | | Total . 82·2 cube in. | 75·2 cube in. | 53·2 cube in. |
| | Per cent. of cylinder capacity | 7 | 6·5 | 4·5 |
| D=22 | Steam port . | 687·3 | 633·3 | 244·3 |
| | Clearance . . | 114·7 | 114·7 | 114·7 |
| H=40 | Recess in cover . | 24·6 | 24·6 | 24·6 |
| | Recess in cover . | 21·5 | 21·5 | 21·5 |
| $n$=65 | Ring in cylinder | 20·0 | 20·0 | 20·0 |
| | | Total . 868·1 cube in. | 814·1 cube in. | 425·1 cube in. |
| | Per cent. of cylinder capacity | 6 | 5·7 | 3 |

**Feet for Cylinders.**

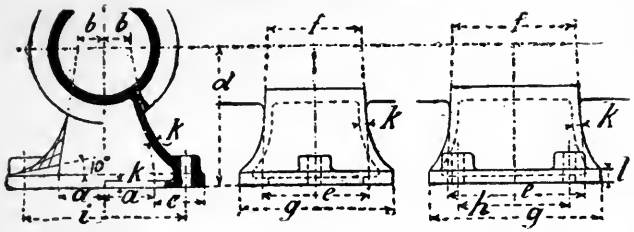



Fig. 348. Fig. 349. Fig. 350.

TABLE 34.—**Dimensions of Cylinder Feet** (Figs. 348—350).

| Engines. | | NOTE.—All Dimensions are in Inches. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* |
| 20 | 10 | 5 | 3 | 5 | 18 | 12 | $10\frac{1}{2}$ | 17 | — | 16 | $\frac{3}{4}$ | $1\frac{1}{2}$ |
| 24 | 12 | $5\frac{1}{2}$ | $3\frac{1}{2}$ | 6 | 20 | 14 | 12 | 20 | 14 | 18 | $\frac{3}{4}$ | $1\frac{3}{4}$ |
| 28 | 14 | $6\frac{1}{2}$ | 4 | $6\frac{1}{2}$ | 22 | 16 | 14 | 22 | 16 | 21 | $\frac{7}{8}$ | 2 |
| 32 | 16 | $7\frac{1}{2}$ | $4\frac{1}{2}$ | $7\frac{1}{4}$ | 24 | 18 | 16 | 25 | 18 | 23 | 1 | $2\frac{1}{4}$ |
| 36 | 18 | 8 | $5\frac{1}{2}$ | 8 | 26 | 20 | $18\frac{1}{2}$ | $27\frac{1}{2}$ | 19 | 26 | $1\frac{1}{8}$ | $2\frac{3}{8}$ |
| 40 | 20 | 9 | 6 | $8\frac{1}{2}$ | 28 | 22 | 19 | 30 | 20 | 28 | $1\frac{1}{4}$ | $2\frac{1}{2}$ |
| 44 | 22 | $9\frac{1}{2}$ | 7 | 9 | 30 | 24 | 21 | 32 | 22 | 30 | $1\frac{1}{4}$ | $2\frac{5}{4}$ |

The expansion of the metal of the cylinder due to the difference in temperature between the cylinder at atmospheric and working heat has occasionally been allowed for by arranging the cylinder foot on a sliding bed, as in fig. 351. The difference in length is given in Table 35. It will be seen that the amount is small, and usually no allowance need be made for it.

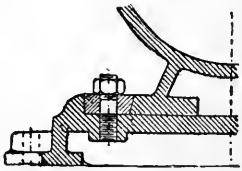


Fig. 351.

TABLE 35.

| Stroke of Engine in Inches. | 16 | 24 | 32 | 39 | 78 |
|---|---|---|---|---|---|
| Amount of expansion, or increase of length —inches . . . | ·0196 | ·0315 | ·0432 | ·0629 | ·1377 |

**Cylinder with Steam Jacket** (see TABLE 36).

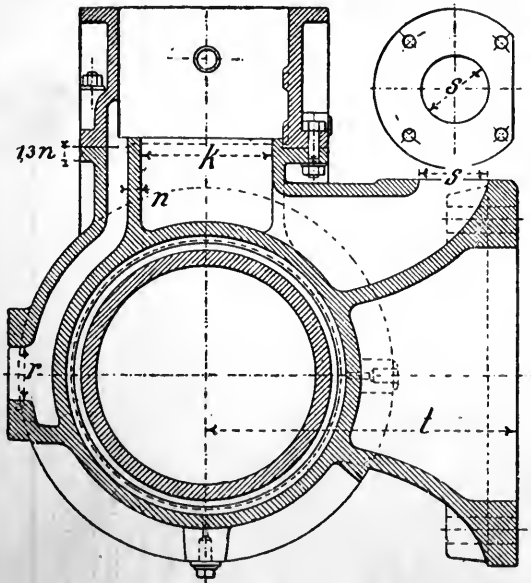



Fig. 352.

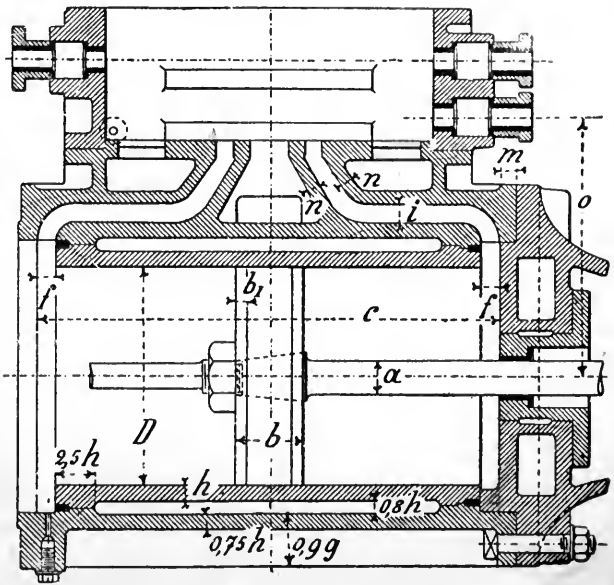



Fig. 353.

## TABLE 36.—Dimensions of Cylinders from 10″ up to 22″ diameter for Double Slide Valves

(Figs. 352, 353, 357, 358.)

| Engine. | | Piston. | | | | | | | | | Steam Ports. | | | | | | Bolts. | | Bolts. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | $a$ | $b$ | $b_1$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ | $m$ | $n$ | $o$ | No. | $p$ | No. | $q$ | $r$ | $s$ | $t$ | $u$ |
| 16 | 8 | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | 10 | $1\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{5}{8}$ | 24 | 1 | 13 | $\frac{13}{16}$ | $4\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $5\frac{3}{8}$ | $18\frac{1}{4}$ | 1 | $\frac{5}{8}$ | $14\frac{1}{4}$ | 4 | $\frac{7}{8}$ | 8 | $\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | 18 | $5\frac{1}{4}$ |
| 24 | 12 | 2 | 4 | $\frac{11}{16}$ | $28\frac{3}{8}$ | $1\frac{5}{16}$ | $15\frac{1}{2}$ | $\frac{7}{8}$ | $4\frac{1}{4}$ | $\frac{7}{8}$ | 1 | $6\frac{3}{4}$ | $20\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | $16\frac{1}{2}$ | 5 | 1 | 8 | $\frac{7}{8}$ | 3 | $3\frac{5}{8}$ | 20 | $6\frac{3}{8}$ |
| 28 | 14 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $\frac{3}{4}$ | 33 | $1\frac{1}{2}$ | 18 | 1 | $4\frac{5}{8}$ | $\frac{15}{16}$ | $1\frac{1}{8}$ | $8\frac{3}{8}$ | $23\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $18\frac{3}{4}$ | 5 | $1\frac{1}{8}$ | 10 | $\frac{7}{8}$ | $3\frac{5}{8}$ | $4\frac{3}{8}$ | 22 | $7\frac{5}{8}$ |
| 32 | 16 | $2\frac{3}{8}$ | $4\frac{3}{4}$ | $\frac{3}{4}$ | $37\frac{1}{4}$ | $1\frac{7}{8}$ | $20\frac{1}{2}$ | $1\frac{1}{16}$ | $4\frac{7}{8}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ | 10 | $25\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $21\frac{1}{4}$ | 6 | $1\frac{1}{8}$ | 10 | $\frac{7}{8}$ | $4\frac{1}{4}$ | 5 | 24 | $8\frac{3}{4}$ |
| 36 | 18 | $2\frac{5}{8}$ | 5 | $\frac{13}{16}$ | $41\frac{5}{8}$ | $2\frac{3}{16}$ | 23 | $1\frac{3}{16}$ | $5\frac{1}{4}$ | 1 | $1\frac{3}{8}$ | $11\frac{5}{8}$ | $28\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $22\frac{1}{2}$ | 6 | $1\frac{1}{4}$ | 10 | 1 | $4\frac{5}{8}$ | $5\frac{5}{8}$ | 26 | $9\frac{5}{8}$ |
| 40 | 20 | $2\frac{3}{4}$ | $5\frac{1}{4}$ | $\frac{7}{8}$ | $45\frac{7}{8}$ | $2\frac{9}{16}$ | $25\frac{1}{2}$ | $1\frac{1}{4}$ | $5\frac{1}{2}$ | 1 | $1\frac{5}{8}$ | $13\frac{1}{4}$ | 31 | $1\frac{1}{2}$ | 1 | $25\frac{5}{8}$ | 8 | $1\frac{1}{4}$ | 12 | 1 | $5\frac{1}{4}$ | $6\frac{3}{8}$ | 28 | 10 |
| 44 | 22 | $3\frac{1}{4}$ | $5\frac{1}{2}$ | $\frac{15}{16}$ | $50\frac{1}{8}$ | $2\frac{3}{4}$ | 28 | $1\frac{5}{16}$ | $5\frac{1}{2}$ | $1\frac{1}{16}$ | $1\frac{3}{4}$ | 15 | 33 | $1\frac{1}{2}$ | 1 | $28\frac{1}{4}$ | 8 | $1\frac{3}{8}$ | 14 | 1 | $5\frac{3}{4}$ | $7\frac{1}{4}$ | 30 | $10\frac{3}{8}$ |

All Dimensions are given in Inches.

### Steam Jackets.

The use of steam jackets is now almost universally adopted in all but very small cheap engines. A well arranged steam jacket tends to keep the steam dry in the cylinder, and slightly reduces the

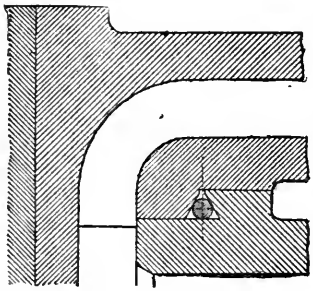


Fig. 354.

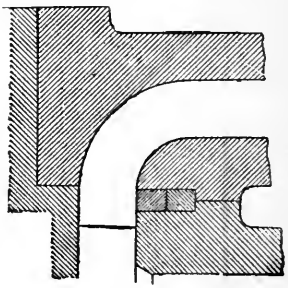


Fig. 355.

amount of steam used per horse power. In some cases the cylinder and jacket are in one casting, but usually the working barrel or liner is separate from the cylinder body, and forced steam tight into it by a hydraulic press. The liner can be made of harder iron than would be safe, if the whole were in one casting. Figs. 352, 353 show methods of rendering the joint between liner and body tight by means of packing. In fig. 353, the packing consists of a copper ring caulked in, but for small work this is quite unnecessary. A good fit is not difficult to obtain, and when the liner is either shrunk in by warming the body, or forced in cold by the hydraulic press, a leak is of very rare occurrence.

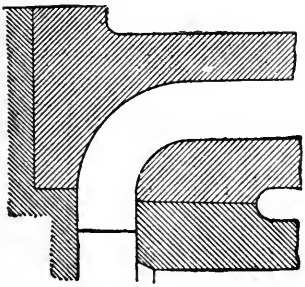


Fig. 356.

## Cylinder for Double Slide Valves.

For dimensions see Table 36, p. 104.

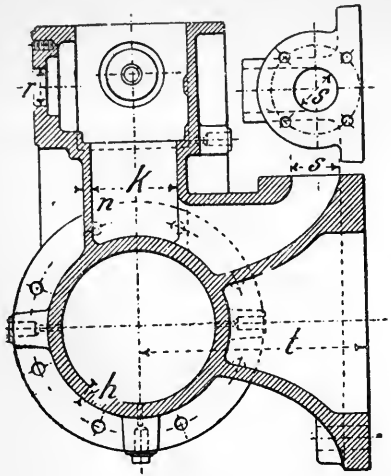



Fig. 357.

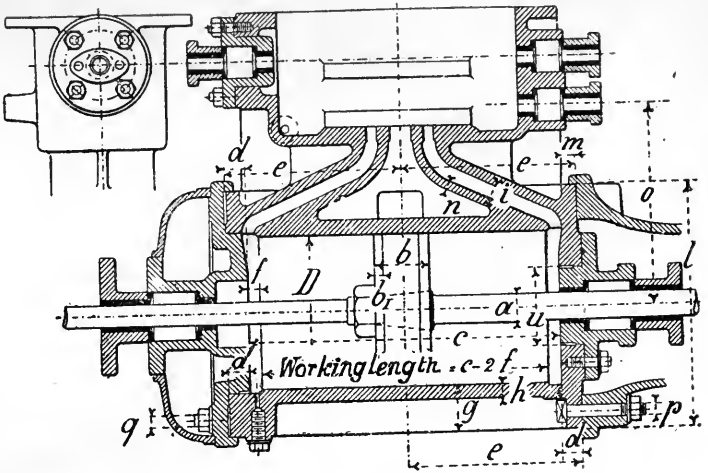



Fig. 358.

**Cylinder for Single Slide Valve** (see TABLE 37).

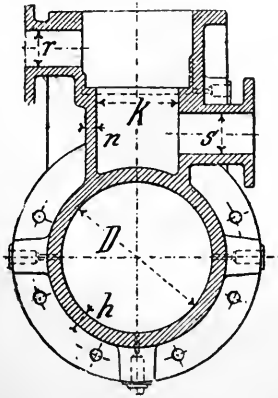



Fig. 359

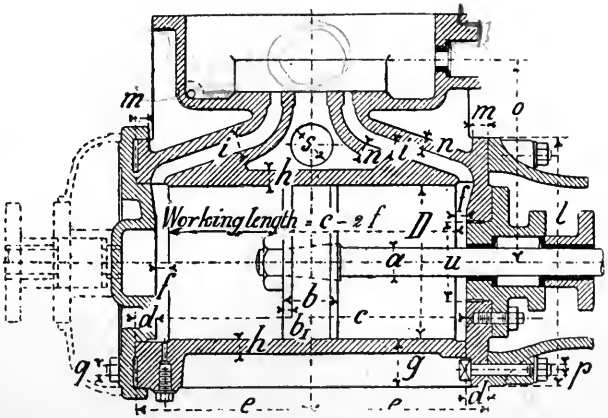



Fig. 360.

TABLE 37.—**Dimensions of Cylinders from 6″ up to 14″ diameter for Single Slide Valve** (Figs. 359, 360).

| Engine. | | Piston. | | | | | | | | | Steam Ports. | | | | | | Bolts. | | Bolts. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | $b_1$ | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | No. | *p* | No. | *q* | *r* | *s* | *u* |
| 12 | 6 | $1\frac{1}{8}$ | 3 | $\frac{1}{2}$ | $15\frac{3}{8}$ | $\frac{9}{16}$ | $8\frac{1}{4}$ | $\frac{3}{4}$ | $3\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $3\frac{1}{4}$ | $13\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | — | 4 | $\frac{3}{4}$ | 6 | $\frac{3}{4}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $3\frac{1}{4}$ |
| 16 | 8 | $1\frac{3}{8}$ | $3\frac{1}{4}$ | $\frac{9}{16}$ | $19\frac{5}{8}$ | $\frac{11}{16}$ | $10\frac{1}{2}$ | $\frac{3}{4}$ | 4 | $\frac{3}{4}$ | $\frac{5}{8}$ | $4\frac{3}{8}$ | 16 | $\frac{7}{8}$ | $\frac{5}{8}$ | — | 4 | $\frac{3}{4}$ | 6 | $\frac{3}{4}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $4\frac{1}{4}$ |
| 20 | 10 | $1\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{5}{8}$ | 24 | 1 | 13 | $\frac{13}{16}$ | $4\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $5\frac{5}{8}$ | $18\frac{1}{4}$ | 1 | $\frac{5}{8}$ | $14\frac{1}{4}$ | 4 | $\frac{7}{8}$ | 8 | $\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $5\frac{1}{4}$ |
| 24 | 12 | 2 | 4 | $\frac{11}{16}$ | $28\frac{5}{8}$ | $1\frac{5}{16}$ | $15\frac{1}{2}$ | $\frac{7}{8}$ | $4\frac{1}{4}$ | $\frac{7}{8}$ | 1 | $6\frac{3}{4}$ | $20\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | $16\frac{1}{2}$ | 5 | 1 | 8 | $\frac{7}{8}$ | 3 | $3\frac{5}{8}$ | $6\frac{3}{8}$ |
| 28 | 14 | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $\frac{3}{4}$ | 33 | $1\frac{1}{2}$ | 18 | 1 | $4\frac{5}{8}$ | $\frac{15}{16}$ | $1\frac{1}{8}$ | $8\frac{3}{8}$ | $23\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $18\frac{3}{4}$ | 5 | $1\frac{1}{4}$ | 10 | $\frac{7}{8}$ | $3\frac{5}{8}$ | $4\frac{3}{8}$ | $7\frac{5}{8}$ |

All Dimensions are given in Inches.

## Attachment of Cylinders to Girder Frames.

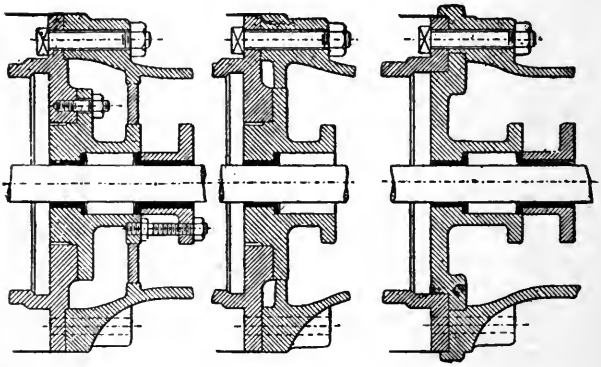


Fig. 361. Fig. 362. Fig. 363.

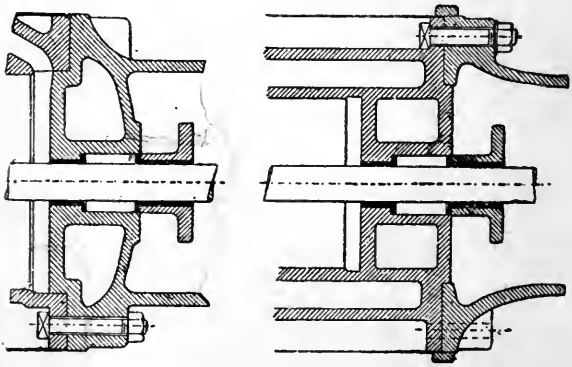


Fig. 364. Fig 365.

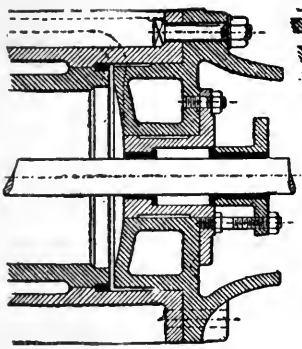


Fig. 366.

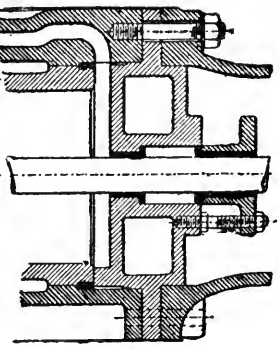


Fig. 367.

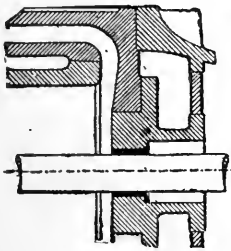


Fig. 368.

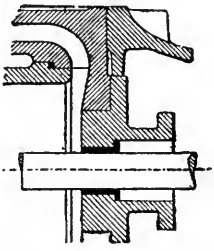


Fig. 369.

Figs. 361 to 369 show different ways of bolting cylinders on to girder frames. Figs. 362, 363, 369 show the simplest and perhaps best way; in fig. 362 the small cover can be removed without disturbing any other part, but in fig. 363 the girder and cylinder must be parted in order to take the cover off, and is therefore not so convenient as figs. 362 and 369. In figs. 364, 366, the girder makes a steam joint with the cylinder; not a good arrangement.

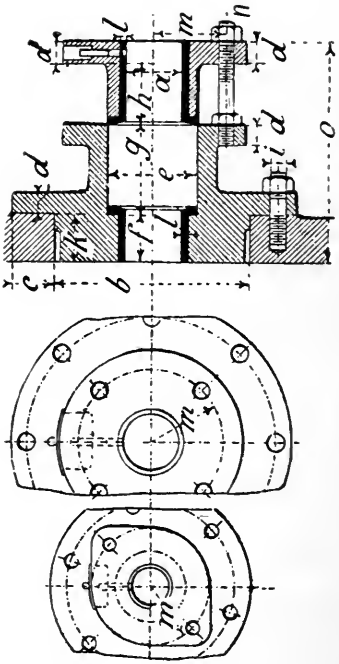



Fig. 372.




Fig. 371.




Fig. 370.

TABLE 38.—**Dimensions of Front Cylinder Covers and Glands** (Figs. 370—372).

| Engine. | | | | | | | | | | Bolts. | | | | | Bolts. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | No. | *i* | *k* | *l* | *m* | No. | *n* | *o* |
| 12 | 6 | $1\frac{1}{8}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | 4 | $\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{3}{16}$ | $2\frac{3}{8}$ | 2 | $\frac{5}{8}$ | 7 |
| 16 | 8 | $1\frac{3}{8}$ | $4\frac{1}{4}$ | 2 | $\frac{7}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{4}$ | 3 | $1\frac{7}{8}$ | 4 | $\frac{5}{8}$ | $1\frac{1}{2}$ | $\frac{3}{16}$ | $2\frac{1}{2}$ | 2 | $\frac{5}{8}$ | $8\frac{1}{4}$ |
| 20 | 10 | $1\frac{5}{8}$ | $5\frac{1}{4}$ | $2\frac{1}{4}$ | 1 | 3 | $1\frac{3}{8}$ | $3\frac{3}{8}$ | $2\frac{1}{8}$ | 6 | $\frac{5}{8}$ | $1\frac{1}{2}$ | $\frac{3}{16}$ | $2\frac{7}{8}$ | 2 | $\frac{3}{4}$ | $9\frac{3}{8}$ |
| 24 | 12 | 2 | $6\frac{3}{8}$ | $2\frac{1}{4}$ | 1 | $3\frac{5}{8}$ | $1\frac{5}{8}$ | 4 | $2\frac{3}{8}$ | 6 | $\frac{3}{4}$ | $1\frac{3}{4}$ | $\frac{1}{4}$ | $3\frac{3}{16}$ | 3 | $\frac{3}{4}$ | $10\frac{1}{2}$ |
| 28 | 14 | $2\frac{1}{4}$ | $7\frac{5}{8}$ | $2\frac{1}{4}$ | 1 | $3\frac{3}{4}$ | $1\frac{3}{4}$ | $4\frac{1}{4}$ | $2\frac{1}{2}$ | 6 | $\frac{3}{4}$ | 2 | $\frac{1}{4}$ | $3\frac{1}{4}$ | 3 | $\frac{3}{4}$ | $11\frac{1}{8}$ |
| 32 | 16 | $2\frac{3}{8}$ | $8\frac{3}{4}$ | $2\frac{3}{8}$ | $1\frac{1}{8}$ | 4 | 2 | $4\frac{1}{4}$ | $2\frac{5}{8}$ | 6 | $\frac{3}{4}$ | $2\frac{1}{2}$ | $\frac{5}{16}$ | $3\frac{3}{8}$ | 3 | $\frac{3}{4}$ | $11\frac{1}{2}$ |
| 36 | 18 | $2\frac{5}{8}$ | $9\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{8}$ | $4\frac{1}{4}$ | $2\frac{1}{4}$ | $4\frac{3}{8}$ | $2\frac{3}{4}$ | 6 | $\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{5}{16}$ | $3\frac{1}{2}$ | 3 | $\frac{3}{4}$ | $12\frac{1}{8}$ |
| 40 | 20 | $2\frac{3}{4}$ | 10 | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $4\frac{3}{8}$ | $2\frac{3}{8}$ | $4\frac{5}{8}$ | 3 | 8 | $\frac{3}{4}$ | 3 | $\frac{5}{16}$ | $3\frac{9}{16}$ | 3 | $\frac{3}{4}$ | $12\frac{3}{4}$ |
| 44 | 22 | $3\frac{1}{4}$ | $10\frac{3}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{4}$ | 5 | $2\frac{3}{4}$ | 5 | $3\frac{3}{8}$ | 8 | $\frac{3}{4}$ | $3\frac{1}{4}$ | $\frac{5}{16}$ | 4 | 4 | $\frac{7}{8}$ | $14\frac{1}{8}$ |

All Dimensions are given in Inches.

**Back Cylinder Covers, with and without Tail Rod Guides.**

Figs. 373 & 374.

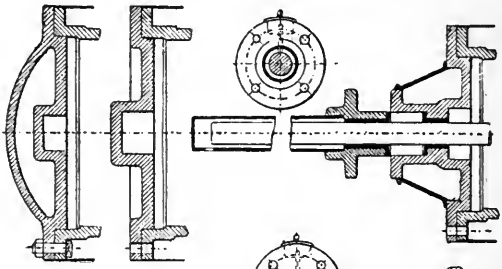


Fig. 375

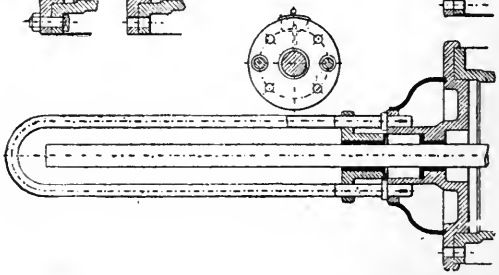


Fig 376.

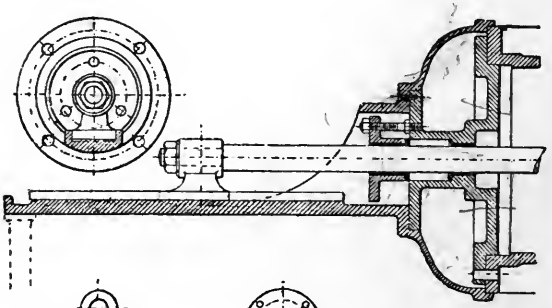


Fig. 377.

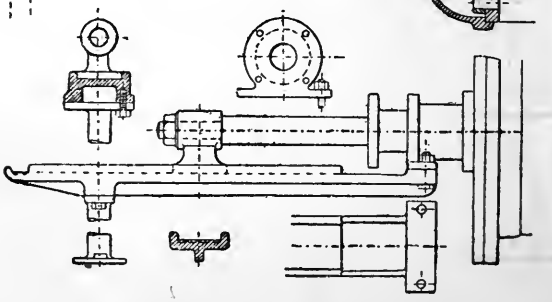


Fig. 378

Fig. 373 shows a chambered cover cast in one piece ; fig 374 a plain back cover. Fig. 375 a simple tail rod guide formed by a stuffing box and gland in back cover and protected by a covering of iron pipe, a very neat arrangement and one that is much used ; fig. 376, the guide for the tail rod, is the same as in the last figure ; the rod is protected by a pair of guard rails, an arrangement which is neither so neat nor good as the tube in fig. 375. In figs. 377, 378 the tail rod guide is more elaborate, being guided by a planed bar and slipper, a more expensive arrangement than those of figs. 375, 376, but more suitable for large engines. Figs. 379, 380 show further methods of guiding the tail rod.

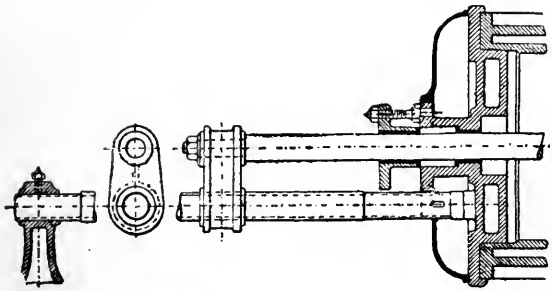


Fig. 379.

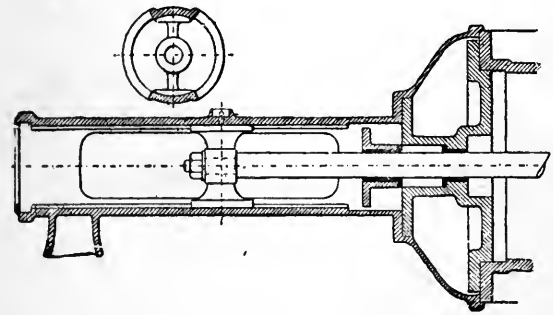


Fig. 380

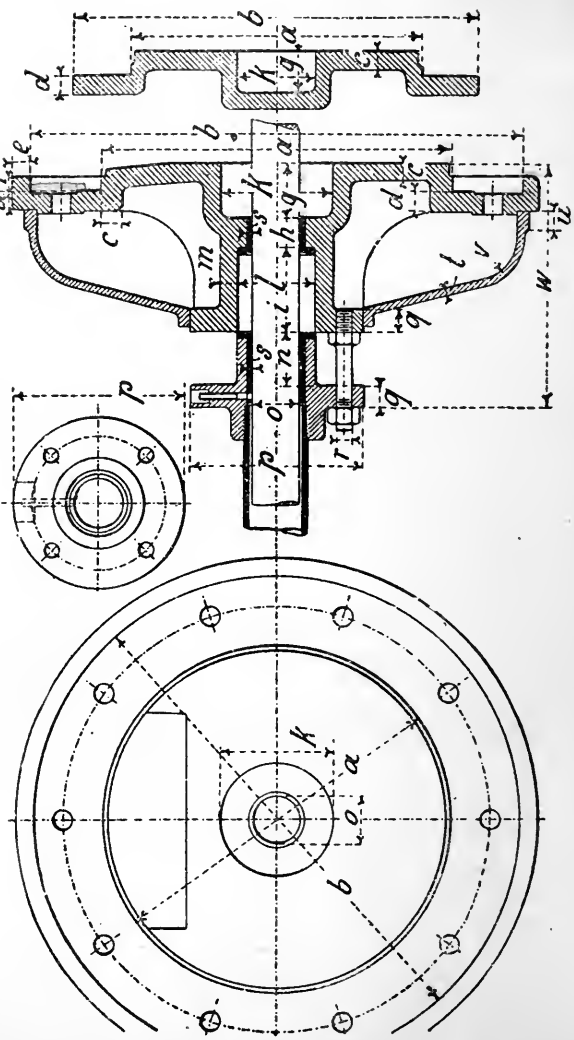


Fig. 381.
Fig. 384.
Fig. 382.
Fig. 383.

TABLE 39.—**Dimensions of Back Cylinder Covers** (Figs. 381—384).

| Engines. | | | | | | | | | | | | | | | | | Bolts. | | | Cover casing. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. | D. | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | No. | *r* | *s* | *t* | *u* | *v* |
| 12 | 6 | $6\frac{1}{2}$ | $13\frac{7}{8}$ | $\frac{3}{4}$ | 1 | — | — | $1\frac{3}{8}$ | — | — | $2\frac{3}{4}$ | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | 8 | $8\frac{1}{2}$ | 16 | $\frac{3}{4}$ | 1 | — | — | $1\frac{3}{4}$ | — | — | $3\frac{1}{2}$ | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | 10 | $10\frac{1}{2}$ | $18\frac{1}{4}$ | $\frac{7}{8}$ | 1 | — | — | $2\frac{1}{4}$ | — | — | $4\frac{1}{2}$ | — | — | — | — | — | — | — | — | — | — | — | — |
| 24 | 12 | $12\frac{1}{2}$ | $20\frac{1}{2}$ | $\frac{7}{8}$ | 1 | $\frac{5}{8}$ | $\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{5}{8}$ | 4 | $4\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{3}{4}$ | $2\frac{3}{8}$ | 2 | $8\frac{1}{4}$ | 1 | 3 | $\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | |
| 28 | 14 | $14\frac{3}{4}$ | $23\frac{1}{4}$ | 1 | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $2\frac{5}{8}$ | $1\frac{3}{4}$ | $4\frac{1}{4}$ | $4\frac{3}{4}$ | $3\frac{3}{4}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | $8\frac{1}{2}$ | 1 | 3 | $\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $2\frac{1}{2}$ |
| 32 | 16 | $16\frac{3}{4}$ | $25\frac{3}{4}$ | 1 | $1\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $2\frac{3}{4}$ | 2 | $4\frac{1}{4}$ | $5\frac{1}{4}$ | 4 | $\frac{7}{8}$ | $2\frac{5}{8}$ | $2\frac{3}{8}$ | $8\frac{5}{8}$ | $1\frac{1}{8}$ | 3 | $\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ |
| 36 | 18 | $18\frac{3}{4}$ | $28\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | 3 | $2\frac{1}{4}$ | $4\frac{3}{8}$ | 6 | $4\frac{1}{4}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | $2\frac{5}{8}$ | $9\frac{1}{4}$ | $1\frac{1}{8}$ | 3 | $\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{3}{4}$ |
| 40 | 20 | $20\frac{3}{4}$ | 31 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 1 | $\frac{3}{4}$ | $3\frac{1}{4}$ | $2\frac{3}{8}$ | $4\frac{5}{8}$ | $6\frac{1}{4}$ | $4\frac{3}{8}$ | $\frac{7}{8}$ | 3 | $2\frac{3}{4}$ | $9\frac{3}{8}$ | $1\frac{1}{4}$ | 3 | $\frac{3}{4}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | $\frac{7}{8}$ | 3 |
| 44 | 22 | $22\frac{3}{4}$ | 33 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 1 | 1 | $3\frac{1}{2}$ | $2\frac{3}{4}$ | 5 | $6\frac{1}{2}$ | 5 | 1 | $3\frac{5}{8}$ | $3\frac{1}{4}$ | $10\frac{1}{8}$ | $1\frac{1}{4}$ | 4 | $\frac{7}{8}$ | $\frac{5}{16}$ | $\frac{1}{2}$ | 1 | $3\frac{1}{4}$ |

All Dimensions are given in Inches.

## Stuffing Boxes and Glands for Piston Rods.

Fig. 385.

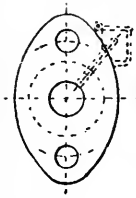
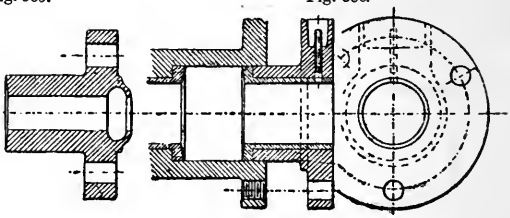


Fig. 386.



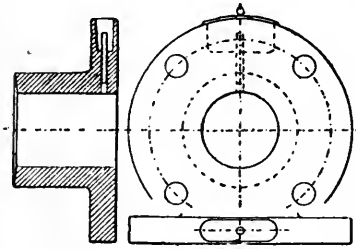


Fig. 387.

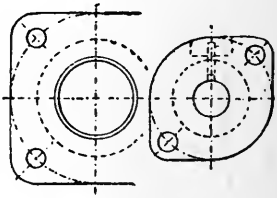


Fig. 388.

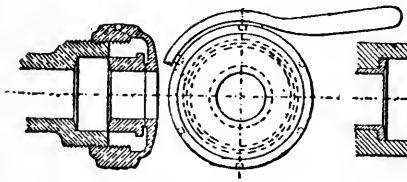


Fig. 389.

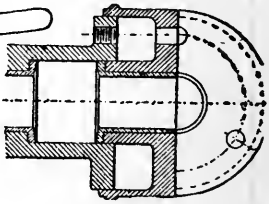


Fig. 390.

Figs. 385, 386 show ordinary simple stuffing boxes and glands; figs. 389, 390 glands of old fashioned type having the disadvantage of often corroding up round the outside of the stuffing box where the cap goes over. Fig. 391 shows the very ingenious device of Mr. Yarrow especially adapted for high speed engines. The piston rod has often given trouble in high speed engines by getting very hot, the reason being that the crosshead guides and cylinder bore are seldom in perfect truth with one another, so that a severe side strain is exerted by the rod against the gland. In Mr. Yarrow's gland this is obviated by introducing loose collars B, B, between

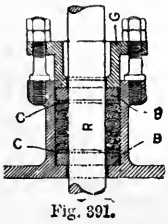



Fig. 391.

the packing and the gland G; these collars are a good fit on the rod but free from touching the sides of the stuffing box; the gland is bored larger than the rod R, but is turned a good fit in the stuffing box. It will be seen in this arrangement if the rod R is guided by the crosshead slightly out of truth with the cylinder bore, the loose collars will allow it to move in its own path freely, the elasticity of the packing allowing of this, and that no severe strain can come upon the gland causing the rod to heat.

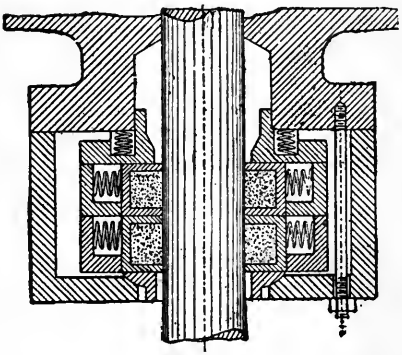
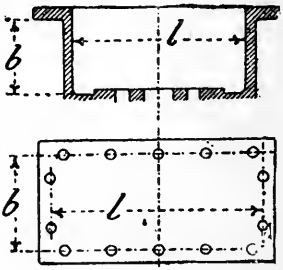


Fig. 392.

Fig. 392 shows a gland and packing made by the United States Metallic Packing Co., Ltd., of Bradford.

## Slide Valve Chests and Covers.

Slide valve chests and their covers are made of cast iron; for calculating the strength of the cover and chest walls, they are considered as plates held fast round the edges (figs. 393, 394).




Figs. 393 and 394.

Thickness of walls, $\delta = \cdot 5l. \sqrt{\frac{Ph}{kl}}$

Stress $k = 0{\cdot}25 \frac{Pbl}{\delta^2}$ = for cast iron 6400 lbs. per square inch.

P = press in lbs. per square inch.
$h$ = breadth of walls.
$l$ = length.

Example.—An engine with $15\frac{3}{4}''$ diameter of piston $27\frac{1}{2}''$ stroke, 88·2 lbs. pressure of steam.

(1.) For the valve chest walls,

$l = 22''$; $b = 11''$; $k = 6400$ lbs. per square inch.

$$\delta = \cdot 5 \times 22 \sqrt{\frac{88{\cdot}2 \times 11}{6400 \times 22}} = \cdot 91'' \text{ about } \tfrac{7}{8}''.$$

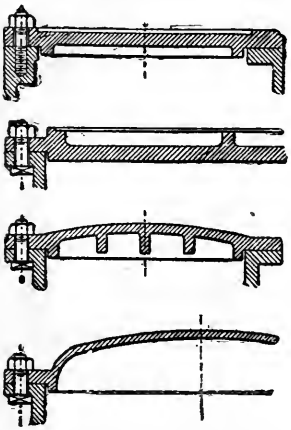
(2.) For the valve chest cover,

$l = 25''$ ; $b = 15''$ ; $k = 6400$ lbs. per square inch

$$\delta = \cdot 5 \times 25 \sqrt{\frac{88 \cdot 2 \times 15}{6400 \times 25}} = 1\tfrac{1}{16}'' \text{ inches.}$$

This $1\frac{1}{16}''$ would be the necessary thickness if the cover were a plain flat plate without stiffening ribs, but as ribs are generally used, except in the case of very small covers, the thickness may be reduced in proportion to the depth and number of ribs. In small engines the valve chest is cast in one with the cylinder, but with very large engines it is often cast separate and bolted on.

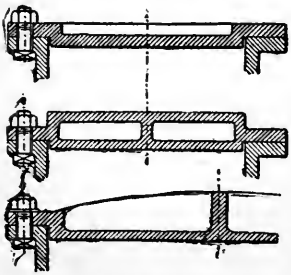
### Valve Chest Covers.



Figs. 395—398.

Valve chests have either internal flanges as figs. 395 and 402, or external flanges as figs. 396 to 401 ; the stiffening ribs are usually on the outside as figs. 396, 402.

The design shown in fig. 402, where the valve chest is finished off with a bold curve, is one that has been largely used on portable engines, and gives an exceedingly neat appearance ; but it is not easy to clothe a valve chest with lagging when the corners are round, as when the corners are square and a small external flange cast on the chest to receive the lagging screws. The cover when ribbed as in fig. 402, is often filled up with non-conducting material and neatly covered over with sheet iron or steel.



Figs. 399—401.

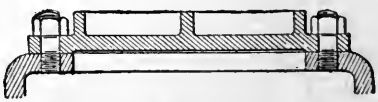


Fig. 402.

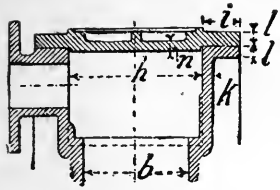



Fig. 403.

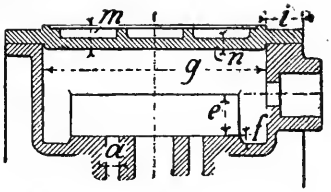



Fig. 404.

TABLE 40.—**Dimensions of Valve Chests of Single Slide Valves** (Figs. 403, 404).

| Engines. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* |
| 12 | 6 | $\frac{3}{8}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | 6 | $4\frac{3}{4}$ | $1\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | 1 | $\frac{3}{8}$ |
| 16 | 8 | $\frac{1}{2}$ | $4\frac{3}{8}$ | 2 | $\frac{1}{2}$ | $7\frac{5}{8}$ | 6 | 2 | $\frac{1}{2}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ |
| 20 | 10 | $\frac{5}{8}$ | $5\frac{5}{8}$ | $2\frac{1}{4}$ | $\frac{1}{2}$ | $9\frac{1}{4}$ | $7\frac{1}{2}$ | $2\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{2}$ |
| 24 | 12 | $\frac{3}{4}$ | $6\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{1}{2}$ | 12 | 9 | $2\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{5}{8}$ |
| 28 | 14 | 1 | $8\frac{3}{8}$ | $2\frac{5}{8}$ | $\frac{1}{2}$ | $14\frac{1}{2}$ | $10\frac{3}{4}$ | $2\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $1\frac{5}{8}$ | $\frac{5}{8}$ |

All Dimensions are given in Inches.

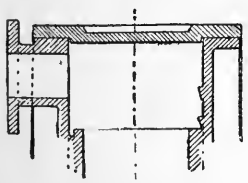


Fig. 405.

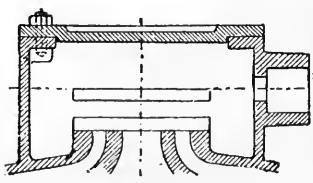


Fig. 406.

Figs. 405, 406 show two sections of a slide valve chest of ordinary construction with raised port face.

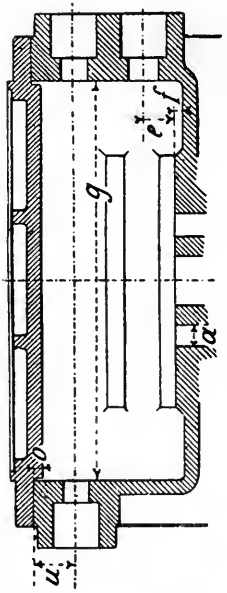



Fig. 407.

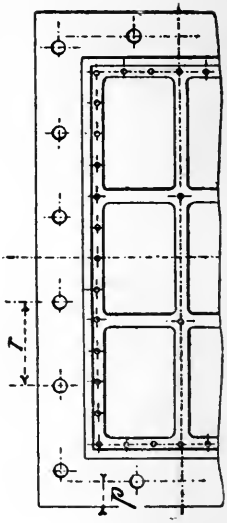



Fig. 408.

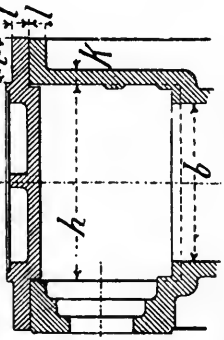



Fig. 409.

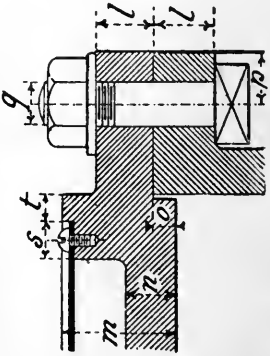



Fig. 410.

TABLE 41.—**Dimensions of Valve Chests with Cover for Meyer's Slide Valves** (Figs. 407—410).

| Engines. | | | | | | | | | | | | | | | Bolts. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | No. | *q* | *r* | *s* | *t* | *u* |
| 16 | 8 | $\frac{1}{2}$ | $4\frac{3}{8}$ | 1 | $\frac{1}{2}$ | $11\frac{1}{4}$ | 6 | 2 | $\frac{1}{2}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{5}{8}$ | 10 | $\frac{1}{2}$ | 4 | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{4}$ |
| 20 | 10 | $\frac{5}{8}$ | $5\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $13\frac{1}{4}$ | $7\frac{1}{2}$ | $2\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{3}{4}$ | 12 | $\frac{5}{8}$ | $4\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | 2 |
| 24 | 12 | $\frac{3}{4}$ | $6\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{2}$ | 16 | 9 | $2\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $\frac{3}{4}$ | 14 | $\frac{5}{8}$ | $4\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{4}$ |
| 28 | 14 | 1 | $8\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | $18\frac{1}{2}$ | $10\frac{3}{4}$ | $2\frac{1}{2}$ | $\frac{3}{4}$ | 1 | 2 | 1 | $\frac{3}{8}$ | 1 | 16 | $\frac{3}{4}$ | $4\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{3}{8}$ |
| 32 | 16 | $1\frac{1}{8}$ | 10 | $1\frac{3}{4}$ | $\frac{5}{8}$ | $21\frac{1}{4}$ | $12\frac{1}{2}$ | $2\frac{3}{4}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{3}{8}$ | 1 | 18 | $\frac{3}{4}$ | $4\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $2\frac{5}{8}$ |
| 36 | 18 | $1\frac{1}{4}$ | $11\frac{5}{8}$ | 2 | $\frac{5}{8}$ | 24 | $14\frac{3}{4}$ | 3 | 1 | $1\frac{1}{4}$ | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{3}{8}$ | $1\frac{1}{8}$ | 20 | $\frac{7}{8}$ | $4\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $2\frac{3}{4}$ |
| 40 | 20 | $1\frac{1}{2}$ | $13\frac{1}{4}$ | 2 | $\frac{3}{4}$ | $27\frac{1}{4}$ | $16\frac{1}{2}$ | $3\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $2\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $1\frac{1}{8}$ | 20 | $\frac{7}{8}$ | 5 | $\frac{5}{8}$ | $\frac{1}{2}$ | 3 |
| 44 | 22 | $1\frac{5}{8}$ | 15 | $2\frac{1}{4}$ | $\frac{3}{4}$ | 30 | 18 | $3\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $2\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{2}$ | $1\frac{3}{8}$ | 22 | 1 | $5\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $3\frac{1}{4}$ |

All Dimensions are given in Inches.

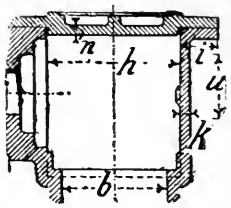



Fig. 411.

TABLE 42.—**Dimensions of Valve Chests for Rider's Slide Valves** (Figs. 411, 412).

| H | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|
| D | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| $u$ | $3\frac{1}{2}$ | $4\frac{1}{2}$ | 5 | 6 | 7 | 8 | 9 |
| $y$ | 15 | $17\frac{1}{2}$ | $20\frac{1}{2}$ | $23\frac{1}{2}$ | $26\frac{1}{2}$ | 30 | 33 |

All Dimensions are given in Inches.

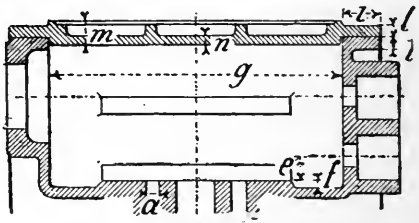



Fig. 412.

## Fly-wheels.

The fly-wheel of an engine may be looked upon as a speed regulator, especially for reducing those irregularities which occur in the engine itself when passing the centres; the fly-wheel also serves to soften down the irregularities proceeding from external causes, such as sudden variations in the load, and thus assists the governor, whose special duty is to control the speed of the engine when under a varying load.

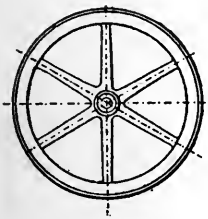


Fig. 413.

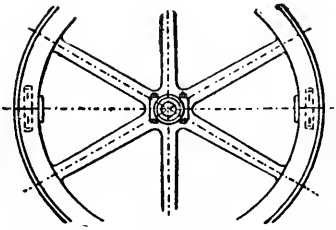


Fig. 414.

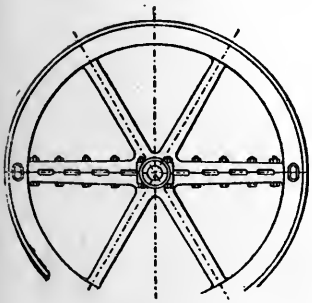


Fig. 415.

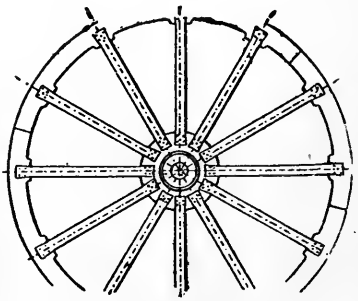
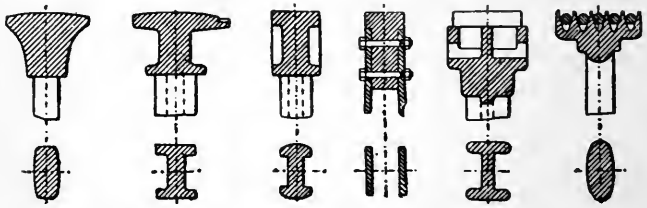


Fig. 416.

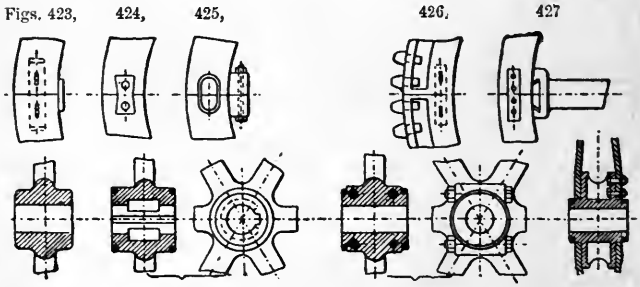
The above figs. show examples of fly-wheels: fig. 414 is the most usual method of making a fly-wheel in halves; fig. 416 shows a built-up wheel with wrought-iron arms, figs. 420 and 431, on page 126 show respectively the section of rim and boss of such a wheel.

Various rules can be given for the weight of fly-wheels, but it should always be remembered that where very steady running is required the fly-wheel should be heavier than most formulæ give, especially if the engine is used, as is often the case, with electric lighting to drive one machine direct; this is perhaps the severest test of steady running that can be given. Where a number of machines are driven from an engine by means of shafting, steady running is not nearly so difficult of attainment, on account of the steadying power of the shafting pulleys, belting, &c.

Engines working with a high rate of expansion require heavy fly-wheels on account of the internal irregularities being greater than when steam is admitted for more than half the stroke.



Figs. 417, 418, 419, 420, 421, 422.



Figs. 423, 424, 425, 426, 427

Figs. 428, 429, 430, 431.

Sections of rims, arms, and bosses of fly-wheels, figs. 417, 418, 419, are ordinary sections of rims and arms; fig. 430, an ordinary fly-wheel boss in halves; other figs. show special examples.

Let N = the effective horse power of the engine.
$n$ = the number of revs. per minute.
$r$ = the crank radius in inches.
$l$ = the length of the connecting rod in inches.
$\frac{r}{l}$ = the ratio of crank radius to length of connecting rod.
G = the weight of the fly-wheel rim in lbs.
R = the mean radius of the fly-wheel rim in feet.
$v$ = the mean speed of the rim in feet per second.
$\frac{1}{\delta} = \frac{v \text{ max.} - v \text{ min.}}{v}$ = the extent of irregularity.
$\delta$ = regularity.

Values of $\delta$—
For ordinary steam engines $\delta$ = 40 to 60.
For engines driving spinning machinery or for electric lighting, } $\delta$ = 60 to 100
For a single cylinder engine,

$$G = 100\, i\, \frac{\delta\, N}{v^2\, n} \text{ and } \delta = \frac{G\, v^2 n}{100\, i\, N}$$

The coefficient $i$ is dependent on the rate of expansion and may be taken from the table where the values of $i$ are given for $\frac{r}{l} = \frac{1}{4}$ to $\frac{1}{6}$ and the clearance space $s$ = from 2 to 7 per cent. of the stroke, and $p$ = absolute initial pressure, $w$ = absolute pressure of release, then $\frac{P}{w}$ = total expansion, and $h$ = the cut off.

TABLE 43.—**Values of $i$.**

| $\frac{P}{w}$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| $h$ | 1 | ·5 | ·33 | ·25 | ·20 | ·15 | ·10 | ·08 | ·06 |
| $i$ | 1265 | 1610 | 1840 | 2070 | 2185 | 2300 | 2415 | 2530 | 2645 |

Example.—For an engine with piston $15\frac{3}{4}''$ diameter, $27\frac{1}{2}''$ stroke, 85 revolutions per minute, 55 effective HP, $\frac{r}{l} = \frac{1}{5}$, R = 5′ 3″

$$v = \frac{85 \times 2\pi \times 5{\cdot}25}{60} = 46{\cdot}5 \text{ feet per second; } h = {\cdot}17,\ \delta = 50.$$

$$G = 100 \times 2185\, \frac{50 \times 55}{(46.5)^2 \times 85} = 3270 \text{ lbs.}$$

The total weight of the fly-wheel, including the arms and boss, is about 1·35 times that of the rim.

For double-cylinder or compound engines, the weight of the wheel may be somewhat less if the cranks are at right angles. $G = 30\, i \frac{\delta\, N}{v^2\, n}$ where N = the total effective HP of the engine and the value of $\delta$ for such engines being rather greater than 70.

Let Gs = the weight in lbs. of a segment whose length is $l$, then $C = \frac{Gsv^2}{gR}$ = the centrifugal force.

The piece $l$, fig. 432, may be taken as a beam with an equally distributed load and fixed at the two ends ; the centrifugal force acting outwards will then be the sum of these equal loads. In order to

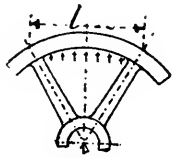


Fig. 432.

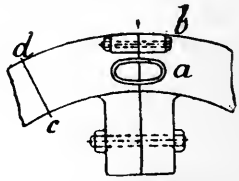


Fig. 433.

increase the strength of the joint in the rim when the fly-wheels are made in halves a wrought iron ring, $a$, fig. 433, is shrunk on over lugs cast on the rim ; (the joint in fig. 433 is of unusual construction, see those shown in figs. 438, 440). The stress $S_1$ on the rim in lbs. per square inch of section may be calculated by the formula, $S_1 = \cdot 144\, v^2$, where $v$ is in feet per second ; this includes the bending strain on the arms. The total stress on the cross section, $c-d$, fig. 433, is $f \times S_1$, where $f$ is the cross section in square inches. If $q$ is the cross section of the two rings taken together and $q_1$ the cross section of the bolts or dowells according to which plan of construction is adopted, then the stress in rings and bolts is $S = \frac{f S_1}{q + q_1}$.

The arms are exposed to a tearing stress from the centrifugal force, and to a bending stress from the variations of the force communicated to the wheel ; the stress may be for cast iron, 1300 lbs. per square inch, for wrought iron, 5000 lbs. per square inch.

The maximum safe velocity for the periphery of a cast iron fly-wheel is usually taken as 80 feet per second, and care must be taken that when the fly-wheel is in halves, that the joints are sufficiently strong to resist bursting, and if not made in halves the boss should be split to allow of contraction in cooling, a hoop being shrunk

on after the wheel is cool.*

Fly-wheels are often used as pulleys for driving machinery by means of belts ; the rim is then turned slightly arched, or if ropes are used, the rim is grooved, as shown in fig. 434.

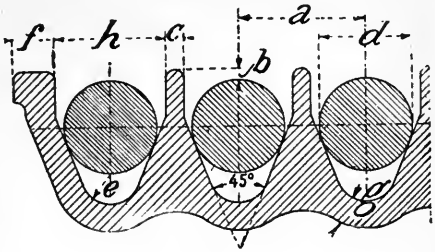



Fig. 434.

TABLE 44.—**Dimensions of Grooves for Rope Pulleys** (Fig. 434).

| *d* | *a* | *b* | *c* | *e* | *f* | *g* | *h* |
|---|---|---|---|---|---|---|---|
| $1\frac{9}{16}$ | $2\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | about $\frac{7}{16}$ | $\frac{5}{8}$ | $\frac{7}{16}$ | $1\frac{13}{16}$ |
| $1\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{3}{16}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | 2 |
| 2 | $2\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $2\frac{1}{4}$ |

All Dimensions are given in Inches.

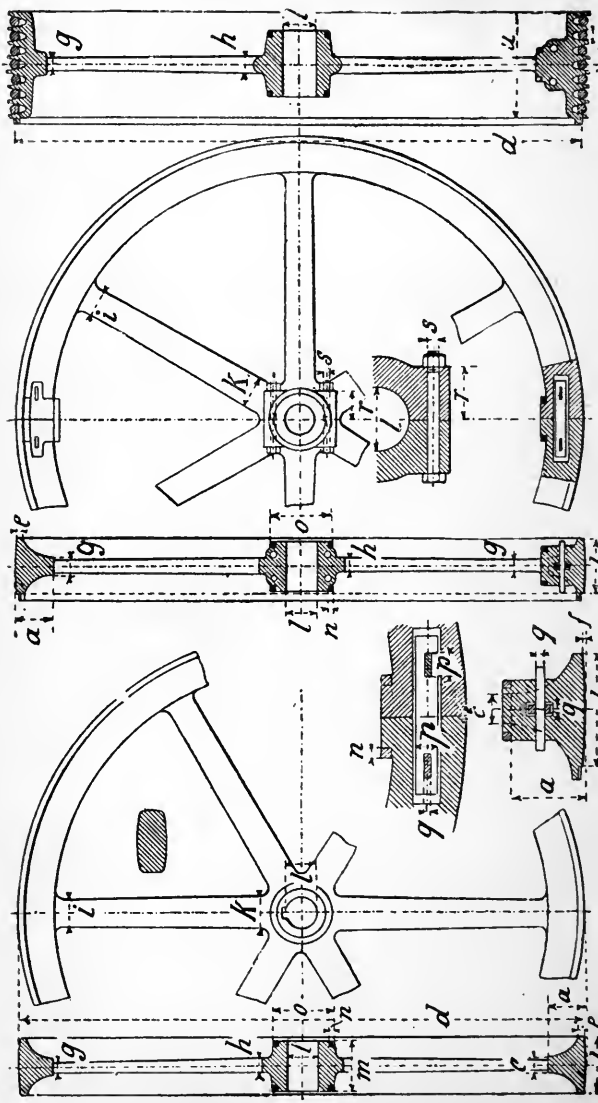
TABLE 45.—**Dimensions and Particulars of Rope Drives.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Circumference of ropes . . | $2\frac{3}{4}$ | 3 | $3\frac{1}{2}$ | $4\frac{1}{4}$ | $5\frac{1}{4}$ | 6 | $6\frac{1}{2}$ |
| Diameter of ropes . . . | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 |
| Weight in lbs. per foot, Hemp | ·37 | ·46 | ·56 | ·66 | 1·00 | 1·37 | 1·62 |
| „ „ „ Cotton | ·27 | ·30 | ·39 | ·59 | ·87 | 1·17 | 1·50 |
| †Diameter of smallest pulley . | 18 | 24 | 30 | 36 | 46 | 60 | 66 |
| Pitch of grooves . . . | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 |
| Indicated HP transmitted by one rope for the above pulleys at 100 revolutions per minute | For ropes running horizonal or nearly so | | | | | | |
| | 2 | 3 | 5 | 12 | 20 | 28 | 36 |
| | For ropes running vertical or nearly so. | | | | | | |
| | 1 | 2 | 4 | 8 | 14 | 20 | 26 |

All Dimensions are given in Inches.

* A fly-wheel, 20 feet diameter, running at 70 revolutions per minute, burst, and the pieces were carried to great distances—the speed in this case being about 70 feet per second.—*Engineer*, Oct. 7th, 1892.

† By "diameter of smallest pulley," it is to be understood that it is best not to use smaller pulleys, except in cases of emergency.



Figs. 435—437.

Figs. 438—440.

TABLE 46.—**Dimensions of Fly-Wheels** (Figs. 435—440).

| Engines. | | | | | | | | | | | | | | | | | | | Centre of gravity of Rim. | Weight of Rim. | Rope Pulleys. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H. | D. | $d$ | $b$ | $a$ | $e$ | $c$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ | $m$ | $n$ | $o$ | $p$ | $q$ | $r$ | $s$ | $d_1$ | lbs. | Ropes No. | $t$ | $u$ |
| 12 | 6 | 42 | 6 | 3 | 2 | $\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | 2 | $2\frac{1}{2}$ | 3 | 5 | — | 6 | — | — | — | — | 40 | 300 | — | — | — |
| 16 | 8 | 60 | 7 | $3\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $3\frac{1}{4}$ | $3\frac{1}{2}$ | 6 | — | 7 | — | — | — | — | 58 | 800 | — | — | — |
| 20 | 10 | 78 | 8 | 4 | $2\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{5}{16}$ | $1\frac{1}{2}$ | 2 | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $5\frac{1}{4}$ | $7\frac{1}{2}$ | 1 | 10 | — | — | — | — | 75 | 1,250 | 3 | $1\frac{1}{2}$ | 7 |
| 24 | 12 | 96 | 10 | 5 | $2\frac{3}{4}$ | $\frac{3}{8}$ | $\frac{5}{16}$ | 2 | $2\frac{1}{2}$ | $4\frac{1}{2}$ | $5\frac{1}{2}$ | 6 | 9 | $1\frac{1}{4}$ | 12 | — | — | — | — | 93 | 1,900 | 4 | $1\frac{1}{2}$ | $8\frac{1}{2}$ |
| 28 | 14 | 114 | 12 | $5\frac{1}{2}$ | $3\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | $2\frac{1}{2}$ | $2\frac{7}{8}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $8\frac{3}{8}$ | $9\frac{1}{2}$ | $1\frac{3}{8}$ | 14 | $2\frac{1}{2}$ | 1 | 5 | $1\frac{3}{8}$ | $110\frac{1}{2}$ | 2,700 | 4 | $1\frac{3}{4}$ | 10 |
| 32 | 16 | 132 | 15 | 6 | $3\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $6\frac{1}{2}$ | $7\frac{5}{8}$ | $9\frac{3}{8}$ | 11 | $1\frac{3}{8}$ | 16 | 3 | $1\frac{1}{8}$ | $5\frac{3}{4}$ | $1\frac{1}{2}$ | 128 | 3,800 | 5 | 2 | $13\frac{1}{2}$ |
| 36 | 18 | 156 | 18 | $6\frac{1}{2}$ | 4 | $\frac{3}{8}$ | $\frac{5}{16}$ | $3\frac{1}{4}$ | $3\frac{3}{4}$ | 7 | $8\frac{3}{8}$ | $10\frac{5}{8}$ | $12\frac{1}{2}$ | $1\frac{1}{2}$ | 17 | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $6\frac{1}{2}$ | $1\frac{5}{8}$ | 152 | 5,100 | 6 | 2 | $16\frac{1}{2}$ |
| 40 | 20 | 168 | 20 | $7\frac{1}{2}$ | $4\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $3\frac{1}{2}$ | $4\frac{1}{2}$ | $7\frac{1}{2}$ | 9 | 12 | 14 | $1\frac{5}{8}$ | 20 | $3\frac{1}{2}$ | $1\frac{3}{8}$ | $7\frac{1}{2}$ | $1\frac{3}{4}$ | 163 | 6,850 | 7 | 2 | 19 |
| 44 | 22 | 192 | 22 | 8 | 5 | $\frac{1}{2}$ | $\frac{3}{8}$ | 4 | 5 | 8 | $9\frac{1}{2}$ | $13\frac{1}{4}$ | 16 | $1\frac{3}{4}$ | 22 | 4 | $1\frac{1}{2}$ | 8 | 2 | 187 | 10,000 | 8 | 2 | 22 |

All Dimensions are given in Inches.

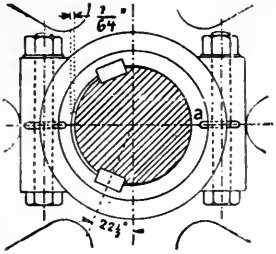



Fig. 441.

An American practice for flywheels is to bore out the boss exactly to the size of the shaft, and then machine or slot out a clearance, as shown to the left of the figure 441, two keys being fitted and driven home. The wheel is thus pulled hard over on to the true part of the original bore.

## Throttle Valves.

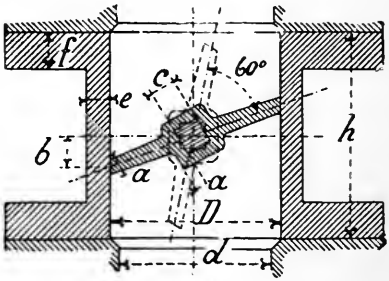



Fig. 442.

TABLE 47.—**Dimensions of Throttle Valves.**

| *d* | D. | *a* | *b* | *c* | *e* | *f* | *h* |
|---|---|---|---|---|---|---|---|
| $\frac{3}{4}$ | $1\frac{1}{4}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | 2 |
| $1\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | $2\frac{1}{2}$ |
| $1\frac{1}{2}$ | 2 | $\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{5}{8}$ | 3 |
| 2 | $2\frac{1}{2}$ | $\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $3\frac{1}{2}$ |
| $2\frac{1}{2}$ | $2\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 4 |
| $2\frac{3}{4}$ | $3\frac{1}{4}$ | $\frac{3}{16}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $4\frac{1}{2}$ |
| $3\frac{1}{4}$ | $3\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 5 |
| $3\frac{1}{2}$ | 4 | $\frac{3}{16}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $5\frac{1}{2}$ |
| 4 | $4\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 6 |
| $4\frac{1}{2}$ | 5 | $\frac{1}{4}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $6\frac{1}{2}$ |
| $4\frac{3}{4}$ | $5\frac{1}{2}$ | $\frac{1}{4}$ | 1 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | 7 |
| $5\frac{1}{4}$ | 6 | $\frac{1}{4}$ | 1 | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $7\frac{1}{2}$ |
| $5\frac{1}{2}$ | $6\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | 1 | 8 |
| 6 | 7 | $\frac{5}{16}$ | $1\frac{1}{8}$ | 1 | $\frac{5}{8}$ | 1 | $8\frac{1}{2}$ |

## SECTION III.

### GOVERNORS.

STEAM-ENGINE GOVERNORS have been greatly elaborated since the time of James Watt's simple conical pendulum governor, and new varieties have been introduced. Governors may be roughly divided into two main types, those in which some form of revolving pendulum is the basis, and those in which the centrifugal force of weights carried on levers is balanced against a spring; the former with a few exceptions revolve on vertical spindles, the latter are usually keyed direct on the engine crank shaft, and are sometimes called "crank shaft" governors. These latter also act directly, in some cases, on the valve eccentric and govern the engine by altering the degree of expansion; the former at the present time are seldom used to control the engine by means of a throttle valve,* as in the earliest engines, but are connected indirectly to the valve gear and control the engine by altering the degree of expansion. There are further sub-divisions into which governors may be divided, such as static, pseudo-astatic, and astatic.

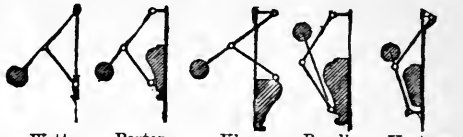
The simple ball governor of Watt is an example of the static governor, and each different speed of revolution corresponds to a definite position of the balls. Astatic governors are too sensitive to be of any use unless indirectly connected with the controlling mechanism, the slightest increase of speed of revolution causing the balls to fly out to their fullest limit; they have, however, been used, when connected to the controlling mechanism, through the medium of three bevel wheels and a clutch (fig. 465).

Pseudo-astatic governors approach nearer to the static governors and are much used; the cross-armed governor of Mr. J. Head (fig. 445) is an example in this kind, and any degree of sensitiveness can be attained by suitable proportions of the arms. When these pendulum governors are combined with a sliding weight as in Porter's governor (fig. 452), they are then called loaded governors, and are better adapted to control an engine than the simple governor of Watt.

* With very quick running engines, the difference whether they are controlled by a throttle valve or by varying the expansion is very small.

## Outlines of Different Types of Governors.

Fig. 443.



Watt. Porter. Kley. Proell. Hartung.

Fig. 444.

Cosinus. Buss. Ericsson. Göpel. Ottos. Gasmot. Girard.

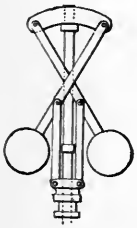


Fig. 445.
Cross-armed.

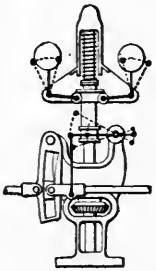


Fig. 446.
Hartnell.

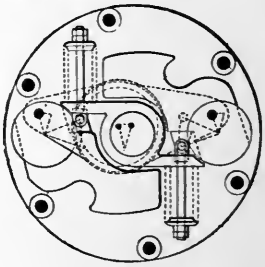


Fig. 447.
Turner—Hartnell.

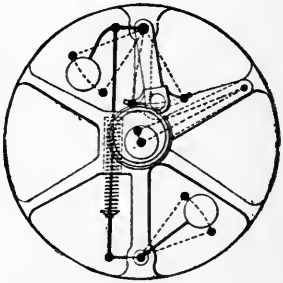
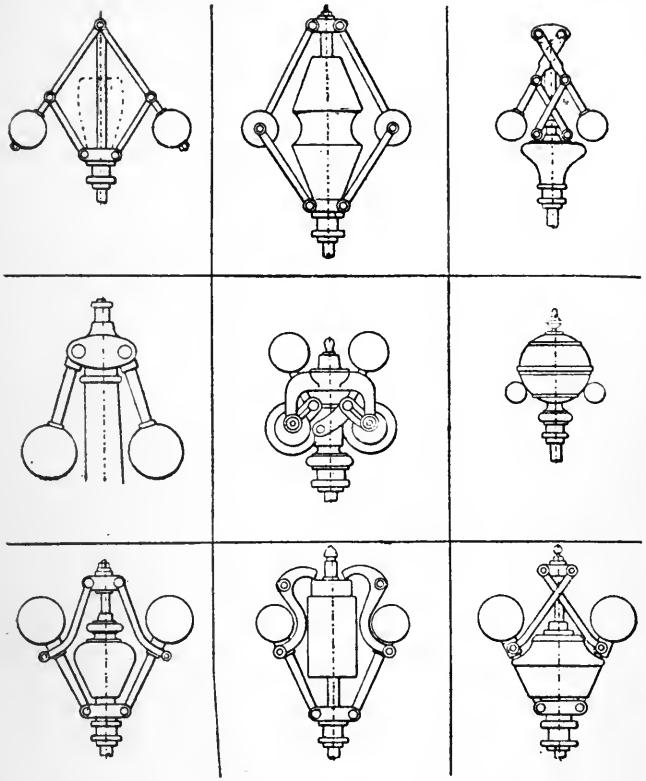


Fig. 448.
Hartnel

Figs. 443—445 show varieties of loaded and unloaded ball governors without springs ; fig. 446, one of Hartnell's loaded centrifugal governors (with spring) on a vertical spindle ; figs. 447, 448 two examples of crank-shaft governors.



Figs. 449—451. Figs. 452, 453, 454. Figs. 455—457.

Varieties of Governors of the Pendulum and Loaded Pendulum Types.

Fig. 449.—Watt.
Fig. 450.—Tangye.
Fig. 451.—Proell.

Fig. 452.—Porter.
Fig. 453.—Buss.
Fig. 454.—Proell.

Fig. 455.—Crossarm. loaded.
Fig. 456.—Cosine.

The formulæ given below serve to show the action of pendulum governors and to calculate the proportions for any given normal speed.

Let P = the weight in lbs. of one ball plus one half the weight of the rod to which it is attached.

Q = the weight in lbs. of the sliding weight plus half the weight of the rod.

R = the resistance offered by the throttle valve or expansion gear actuated by the governor together with the resistance of the governor itself.

$n_1$, $n$, $n_{11}$, = the greatest, normal and least number of revolutions per minute of the governor.

$\beta_1$, $\beta$, $\beta_{11}$, = the greatest, normal and least angle between the rods and the spindle.

$\frac{1}{\delta_0}$ = the irregularity of the fly-wheel speed.

$\frac{1}{\delta} = \frac{n_1 - n_{11}}{n}$ the irregularity of the speed of the engine and consequently also of the governor; $\frac{1}{\delta}$ = about $\cdot 9\ \frac{1}{\delta_0}$.

S = the distance in inches which the sliding weight moves up and down.

An ordinary approximate formula for calculating the height of cone of revolving pendulum governor for any number of revolutions per minute N, 's; $N = \frac{187{\cdot}5}{\sqrt{L}}$ and $L = \left(\frac{187{\cdot}5}{N}\right)^2$ where L = height of cone in inches measured from plane of rotation of the centre of the balls to the point where the centre lines of the arms carrying the balls cross on the centre line of spindle. For a loaded governor the height of the cone is increased for a given speed in the ratio 2P + 2Q : 2P; where P = weight of one ball and half the arm in lbs., and Q the load or sliding weight and half arm in lbs.

$d$ = diameter in inches of the balls. For the normal speed $n$, R is taken to equal 0 in the equations.

Watt's governor, fig. 458.

$$n^2 = \frac{2936}{a \cos. \beta}\left(1 + \frac{Qb}{Pa}\right); \quad \frac{1}{\delta} = \frac{Rb}{Pa + Qb}.$$

Dimensions in feet; the constant 2936, in from $\frac{3600g}{4\pi^2}$ where $g = 32{\cdot}2$.

The following proportions will be found to give good results—

$\frac{Q}{P}$ = 0 to 4, $\frac{b}{a}$ = ·6, S = ·12$b$, $\beta$ = 25°, $\frac{1}{\delta}$ = ·03.

For Porter's governor, fig. 459.

$$n^2 = 2936 \frac{1 + \frac{Q \pm R}{P}}{a \cos. \beta + e \cot. \beta}$$

$$\frac{1}{\delta} = \frac{R}{P + Q}, \text{ dimensions in feet.}$$

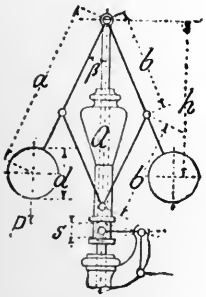



Fig. 458.

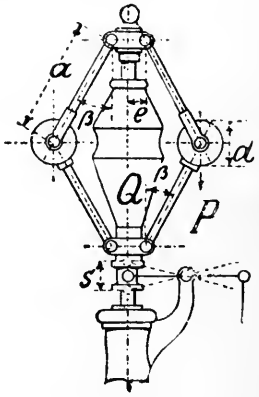



Fig. 459.

Table 48 gives the leading dimensions for a few examples of Porter's governor.

TABLE 48.

| $n$ = | 150 | 140 | 130 | 120 | 110 | 100 | 90 |
|---|---|---|---|---|---|---|---|
| $a$ = | $8\frac{3}{4}$ | $10\frac{3}{8}$ | 12 | $14\frac{3}{8}$ | $18\frac{2}{4}$ | 20 | 24 |
| $e$ = | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{5}{8}$ | 2 | $2\frac{3}{8}$ |
| $s$ = | $1\frac{1}{8}$ | $1\frac{1}{2}$ | 2 | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $3\frac{5}{8}$ |
| $d$ = | $3\frac{1}{4}$ | $4\frac{1}{4}$ | $5\frac{1}{4}$ | 6 | $6\frac{3}{4}$ | $7\frac{5}{8}$ | 8 |

All Dimensions are given in Inches.

Kley's governor (astatic), fig. 460.

$$n^2 = \frac{2936}{a \cos.\ \beta - e \cot.\ \beta}\left(1 + \frac{Qb}{Pa}\right)$$

$$\frac{1}{\delta} = \frac{Rb}{Pa + Qb}$$

Proell's governor (pseudo-astatic), fig. 461.

$$n^2 = 2936\ \frac{-1 + \frac{Q + 2P \pm R}{P} \times \frac{b}{a} \times \frac{\sin.\ \gamma}{\sin.\ \beta}}{a \cos.\ \beta + e \cot.\ \beta}$$

$$\frac{1}{\delta} = \frac{R}{-P\frac{a}{b} \times \frac{\sin.\ \gamma}{\sin.\ \beta} + Q + 2P}$$

dimensions in feet.

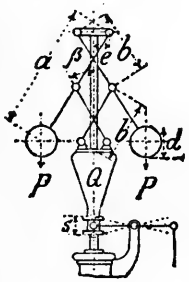



Fig. 460

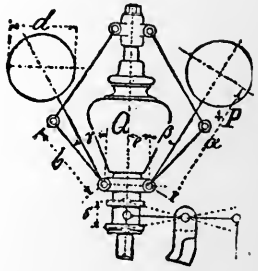



Fig. 461

TABLE 49.—**Leading Dimensions of Kley's Governor** (Fig. 460).

$\frac{a}{b}$ = ·7 to ·5.

$\frac{Q}{P}$ = about 4.

$\beta$ = 30°.

| $n$ = | 110 | 100 | 90 | 85 | 80 | 75 | 70 |
|---|---|---|---|---|---|---|---|
| $a$ = | $13\frac{3}{8}$ | $15\frac{5}{8}$ | 18 | $21\frac{3}{4}$ | $25\frac{3}{8}$ | 30 | 36 |
| $e$ = | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{5}{8}$ | 2 | $2\frac{3}{8}$ |
| $s$ = | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $3\frac{3}{8}$ | 4 | $4\frac{3}{4}$ | $5\frac{5}{8}$ |
| $d$ = | $4\frac{5}{8}$ | $5\frac{3}{8}$ | 6 | $7\frac{1}{4}$ | $8\frac{3}{8}$ | 10 | $11\frac{1}{4}$ |

All Dimensions are given in Inches.

TABLE 50.—**Leading Dimensions of Proell's Governor** (Fig. 461).

$\frac{Q}{P}$ = about 4.

$\beta = 20°$.

$\gamma = 30°$.

| $n =$ | 135 | 125 | 115 | 110 | 105 | 100 | 95 |
|---|---|---|---|---|---|---|---|
| $a =$ | 8 | $9\frac{5}{8}$ | $11\frac{1}{4}$ | $12\frac{3}{4}$ | $14\frac{3}{8}$ | $16\frac{3}{8}$ | $18\frac{3}{8}$ |
| $b =$ | $5\frac{3}{8}$ | $6\frac{3}{4}$ | $7\frac{3}{4}$ | 9 | 10 | $11\frac{3}{8}$ | $12\frac{3}{4}$ |
| $e =$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{5}{8}$ | 2 | $2\frac{3}{8}$ |
| $s =$ | 2 | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{4}$ |
| $d =$ | 4 | $4\frac{3}{4}$ | $5\frac{5}{8}$ | $6\frac{3}{8}$ | $7\frac{1}{4}$ | $8\frac{1}{4}$ | $9\frac{1}{4}$ |

All Dimensions are given in Inches.

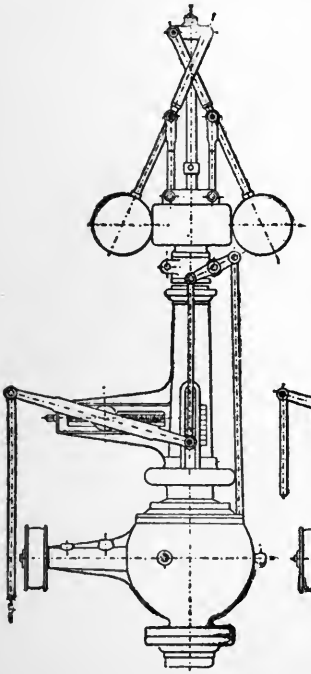


Fig. 462.

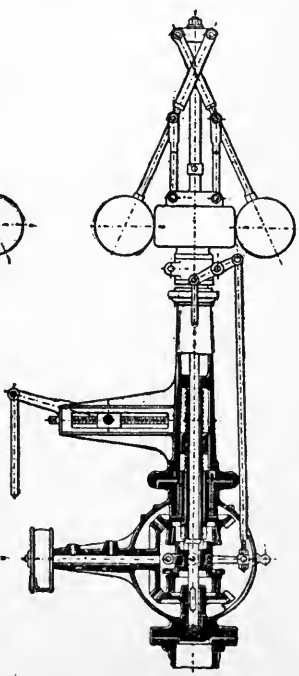


Fig. 463.

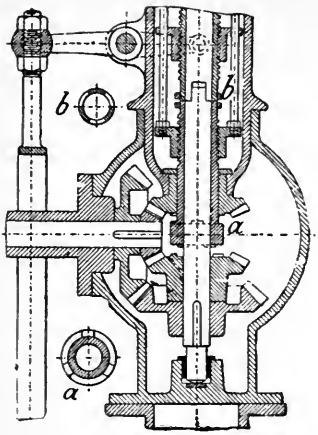



Fig. 464.

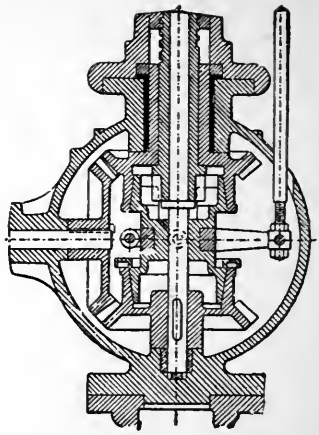


Fig. 465.

Figs. 462—465 give examples of cross-armed governors on stands with clutch and bevel-wheel gear.

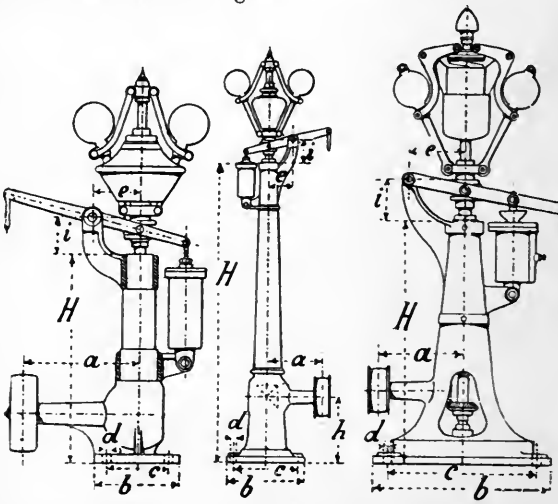



Fig. 466. Fig. 467. Fig. 468.

Figs. 466—468 give examples of governors made by the Lauchammer Iron Works fitted with an oil-brake or dash-pot, with a table of dimensions

TABLE 51.—**Leading Dimensions of the Lauchammer Governors** (Figs. 466—468).

| Distinguishing No. | I. | II. | III. | IV. |
|---|---|---|---|---|
| Height of stand, H | $21\frac{5}{8}$ | 61 | $37\frac{3}{8}$ | $42\frac{1}{2}$ |
| Dimension $a$ | $9\frac{7}{8}$ | $11\frac{1}{2}$ | 13 | $14\frac{3}{4}$ |
| „ $b$ | $8\frac{5}{8}$ | $15\frac{3}{4}$ | $27\frac{5}{8}$ | $31\frac{1}{2}$ |
| „ $c$ | $6\frac{1}{4}$ | 13 | $23\frac{5}{8}$ | $27\frac{1}{8}$ |
| „ $d$ | $\frac{3}{4}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| „ $e$ | $4\frac{3}{8}$ | $4\frac{7}{8}$ | $8\frac{5}{8}$ | $9\frac{7}{8}$ |
| „ $i$ | $4\frac{7}{8}$ | $4\frac{1}{2}$ | $6\frac{3}{8}$ | $7\frac{1}{8}$ |
| Weight in lbs. complete as shown in figures | 660 | 704 | 750 | 840 |

All Dimensions are given in Inches.

Fig. 466 is especially adapted for horizontal engines; fig. 467 for vertical engines; fig. 468 a heavy type with a spring enclosed in a case in place of the sliding weight.

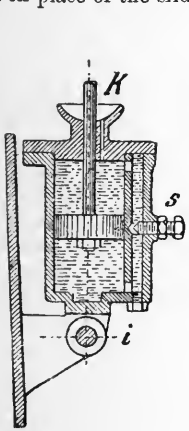



Fig. 469.

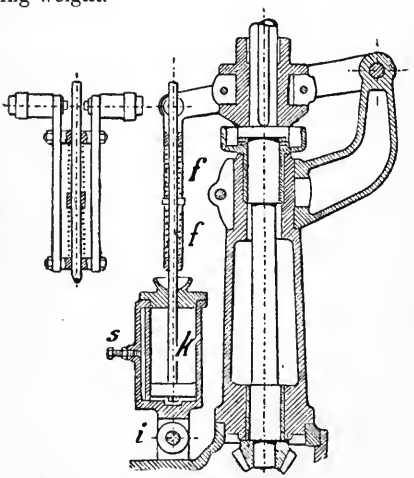



Fig. 472. Fig. 470. Fig. 471.

To prevent sudden and violent fluctuations of the governor an oil-brake or "dash-pot" is often added; examples of dash-pots applied to governors are shown in Figs. 469—471. The cylinder of the dash-pot, fig. 469, is jointed to the frame or stand of the governor, by the pin *i*.

The cylinder is filled with oil or glycerine, and as the piston is moved up or down, the oil passes from the upper to the lower side of the piston by a passage shown at the side of the cylinder; this passage can be more or less throttled by the screw S, so as to give more or less resistance to the movement of the piston, and thus "damp" the tendency to violent fluctuations in the governor. The screw S can be adjusted whilst the engine is running. Fig. 471 shows a combination of dash-pot with an elastic connection between the governor lever and piston rod of dash-pot, a spiral spring being inserted as shown at *f f*, fig. 471. This elastic connection assists the damping action of the dash-pot and should be conducive to very steady running. In some cases the dash-pot is incorporated with the governor, and enclosed in a neat case.

### Automatic Expansion Governor by Wilson Hartnell (Fig. 473).

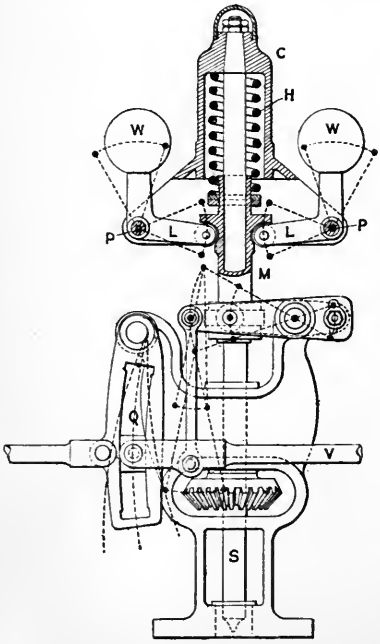



Fig. 473.

This governor is driven by bevel wheels and pulleys from the crank shaft of the engine, and consists essentially of a vertical spindle, S, carrying a casting, C; two weights, W W, on bell-crank levers, L L, are jointed on to C, by means of pins, P P; the inner ends of the levers are in contact with the sleeve M, against which the spring H presses; the lower part of the sleeve M is connected by means of a ring and rods, to the valve rod V; when the sleeve M rises, the block in the link Q is raised, and thus a varying stroke is given to the valve, the link Q being moved by an eccentric. The centrifugal force of the weights W W, through the medium of the levers L L, tends to compress the spring H. The

motion of the different parts is clearly shown in the fig. by the dotted lines.

This governor is much used for controlling the speed of engines, by varying the cut-off, and is usually applied to valve gears with two valves, the main valve driven by an eccentric in the usual way, the cut-off by a separate eccentric through the medium of the link on the governor by which the cut-off is varied.

### Crank-Shaft Governors.

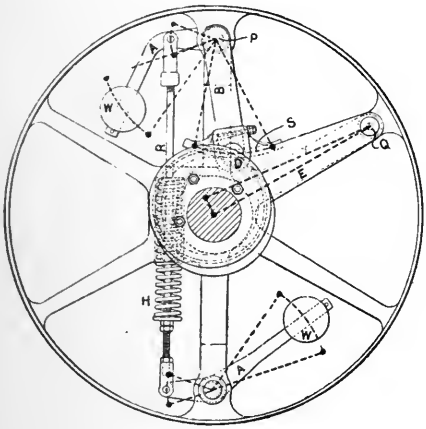



Fig. 474.

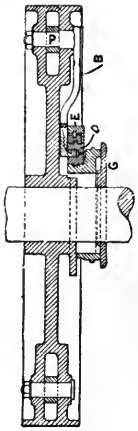



Fig. 475.

Figs. 474, 475, show two views of a Hartnell crank-shaft governor for controlling the speed of an engine by varying the cut-off. In the above figures the governor is shown in a six-armed wheel or pulley ; in some cases the governor is carried in the fly-wheel itself. Two weights, W W, are carried on two levers, A, turning on pins in the arms of the wheel ; the two levers are connected together by the rod R by means of joints and pins, and when the weights move outwards by centrifugal force they tend to compress the spring H. The upper lever, fig. 474, is rigidly fixed to its centre pin, and this pin carries the arm B, terminating at the lower end in the sector S, so that when the weight W moves outwards or inwards the sector S moves to the right or left. The sector is formed as shown in the cross section, fig. 475, and engages in the swivel block D. The block D is free to turn in a recess formed to receive it, in the arm of the

eccentric E, this arm being centred on the pin Q. On referring to fig. 474 it will be seen that the sector S is not concentric with the centre P, upon which it swings, but its centre lies to the right hand of the centre P, so that the sector is inclined, the right hand end being the lower. Now as the sector swings on centre P towards the left, and in sliding through the block D pushes the eccentric arm E downwards, and as the eccentric itself is attached to the arm E, its centre will approach towards the centre of the crank-shaft, and thus the stroke of the eccentric will be reduced and the steam cut off earlier. In the figure the line in which the centre of the eccentric approaches the centre of the shaft is radial, and the governor is for application to a separate cut-off valve of the gridiron type working on the balk of the main valve. For engines with only a single valve, the line in which the centre of the eccentric approaches the centre of the crank-shaft is not radial but parallel to radial line such as that in the figure, but at a distance equal to the lap and lead from the crank-shaft centre. It will be seen that one important feature in these crank-shaft governors, is that they are keyed fast on the shaft, and not being driven by means of belts or gear, can lead to no accident from belt slipping or gears breaking ; and if the spring should break, the weights would fly out to their extreme limits and diminish the supply of steam to nothing, so the engine would slow down until nearly stopped. These governors are extremely sensitive and well adapted for high speeds : with very slow running-engines they become rather heavy. For calculating the springs the following simple formula is used :—

$W$ = weight in lbs. of one of the weights.
$N$ = normal speed in revolutions per minute.
$N_1$ = minimum speed in revolutions per minute.
$N_2$ = maximum speed in revolutions per minute.
$N_2 - N_1$ = allowed variation, upon the limit of this variation the sensitiveness of the governor largely depends ; about 3 per cent. under and 4 per cent. over the normal speed gives good results, and the usual variations in load of an engine in ordinary working conditions will not give nearly as much variation in speed.
$R_1$ = the radius in inches from centre of shaft to centre of weight when the latter is nearest to the centre of the shaft and corresponds to the speed of $N_1$.
$R_2$ = the corresponding radius to the speed of $N_2$.
$L$ = the length ir inches of the lever carrying the weight.

$l$ = the length in inches of the lever to which the spring rod R is attached.

$r$ = the distance through which the spring is compressed by the action of the governor.

$P_1$ = the load on the spring in lbs. due to the centrifugal force at the minimum speed.

$P_2$ = the corresponding load in lbs. due to the maximum speed.

The $P_2 - P_1$ will equal the difference of maximum and minimum loads and $\left(\frac{P_2 - P_1}{r}\right) 2$ will equal the load in lbs. per inch of compression of the spring as the two weights act together on the spring.

$$P_1 = \frac{W \times R_1 \times N_1^2 \times L \times \cdot000028}{l},$$

$$P_2 = \frac{W \times R_2 \times N_2^2 \times L \times \cdot000028}{l}.$$

Spring-makers seem to be very successful in making springs accurate enough for such purposes as centrifugal governors from such data as stiffness per inch required, maximum load to which the spring will be subjected, external diameter and length when uncompressed.

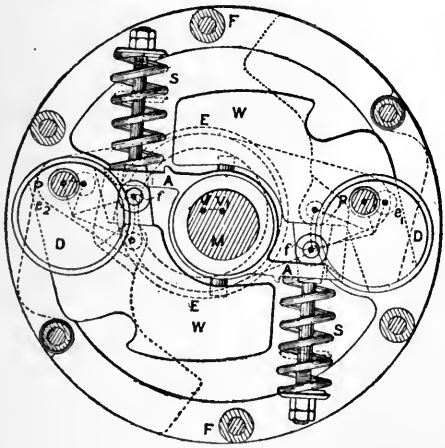



Fig. 476.

A modification of Hartnell's crank shaft governor, has been introduced by Messrs. Turner, of Ipswich, shown in diagram in fig. 476, and in perspective in figs. 477, 478.

Referring to fig. 476, two weights, W W, are formed with turned bosses, D D, fitted to and free to turn in holes in the plates or discs which form the governor body, and which are keyed on the crank shaft, M, the weights thus turning with the shaft and discs, and having their centrifugal force balanced by the springs, S S; the weights are connected by the eccentric, E (shown in dotted lines), by means of the pins, P P; the weights are shown in fig. 476, closed in full lines, and open in dotted lines. It will be seen that by the weights open-

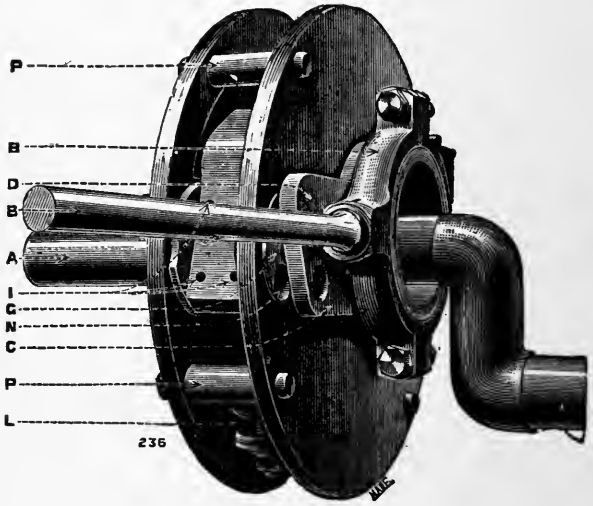



Fig. 477.

ing outwards, the pins, P P, move towards the left, and carry the eccentric with them, the centre of the eccentric moving from V to $V_1$, the stroke being thereby reduced, the result being nearly the same as in the Hartnell governor, and the action on the valve almost as if the variation in the cut-off were effected by an ordinary Stephenson link motion.

In fig. 477, the outside view of the Turner-Hartnell governor is shown with the eccentric rod attached; in fig. 478, one side disc is removed, and the weights shown open.

The reference letters are, A, the engine crank shaft; B, the valve eccentric rod; C, the eccentric; D D, pins carrying the eccentric, and passing through the bosses of the weights; H H, the weights;

P, bolts with collars and nuts, forming stanchions or pillars for holding the discs together.

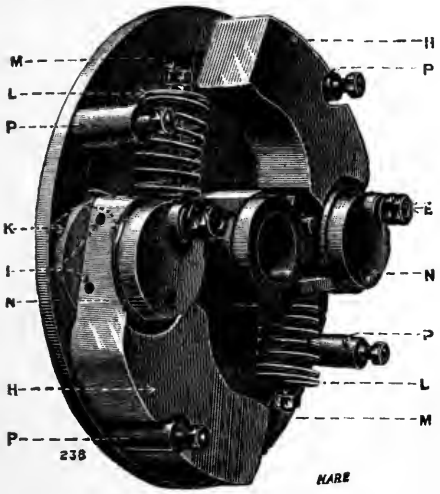



Fig. 478.

Another variety of crank shaft governor, is that of Mr. Moore, made by Messrs. Marshall, of Gainsborough. Figs. 479—482, show the different parts, and the governor consists of a heavy loose rim, A, attached to the shaft through an elastic arrangement of links carrying the weights; C C, are the weights turning on centres attached to the rim; D D, the springs; B B, links connected at one end to the weights and at the other to the points, H H, on the tripod G, fig. 482; the arm of the eccentric, E, fig. 481, is centred on the single end of G, fig. 482, at I; the link F connects the eccentric E to the rim A.

The rim A revolves with the shaft, but is capable of running round the shaft to a small extent, defined by the limit of extension and contraction of the link centres, that is, by the extent to which the weights will open out, which can be regulated by stops on the back of the weights.

In connection with the loose rim is a variable expansion eccentric, shifting with the rim and increasing or decreasing the stroke of the eccentric and valve, and thus varying the cut-off. The action of this governor is peculiar, and may be explained as follows:—The inertia of the rim assists the weights to rise; the momentum of the rim, by

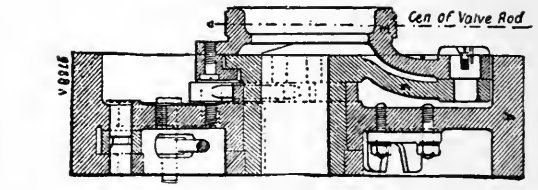



Fig. 479.

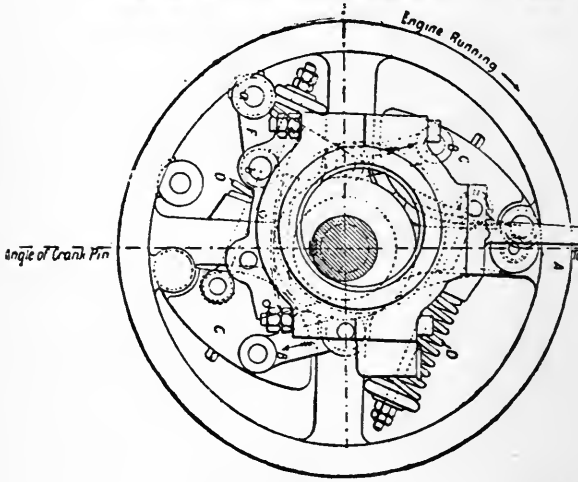
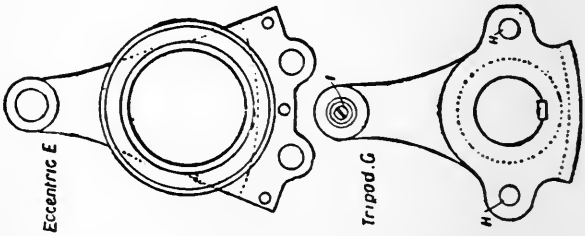



Fig. 480.




Figs. 481, 482.

straightening out the link and weight when the speed of the shaft diminishes, assists the weights to fall.

When the governor is expanding (rising), with an increasing speed, the shaft acts against the rim, through the link and weight, as shown by the arrow. When the governor is closing (falling) with a diminishing speed, the rim acts against it, tending to pull it forward, straightening out the link and weight. The weights are maintained in a larger plane of revolution, so to speak, than that due to centrifugal force, by the governor acting against the inertia of the rim when rising, *i.e.*, speed increasing. The weights are maintained in a smaller plane of revolution than that due to centrifugal force by the momentum of the rim acting against the governor, tending to pull it forward when closing, *i.e.*, speed decreasing.

The governor has a tendency to go too far both ways, either up or down, whenever there is the slightest variation above or below the normal speed, this tendency is checked by the work done by the governor in shifting the eccentric and valve. From the assistance given to the action of the governor weights by the rim, this governor is extremely sensitive.

# SECTION IV.

## VALVE GEARS.

### Indicator Diagrams.

In order to follow the effect of the different distribution of steam effected by different valve gears, it is necessary to understand the indicator diagram. By the term "indicator diagram" is to be understood the graphic representation of the varying pressure of the steam on the engine piston at all positions of the crank. The steam engine "Indicator" invented by James Watt is the instrument by which the diagrams are automatically drawn. A brief description of indicators will be found on page 373. Figs. 483—488 show a few ideal forms of diagrams, with the following letters of reference :—

H = the stroke of the piston.

$h$ = length of the period during which steam is admitted. If H be taken to equal 1, then $\frac{H}{h}$ = the ratio of expansion.

$p$ = the initial absolute pressure measured from the line of perfect vacuum. $p$ is usually taken in lbs. per square inch, but may sometimes be conveniently taken in atmospheres.

$p_m$ = the average or mean effective pressure on the piston.

$w$ = the terminal pressure.

$p_o$ = the back pressure.

$s$ = the clearance and steam passage for one end of the cylinder, usually taken in cubic inches or feet, and in diagrams figs. 483—488 it is expressed in terms of the piston area, so that the line $s$ represents the volume of the clearance space.

$va$ = the line of perfect vacuum.

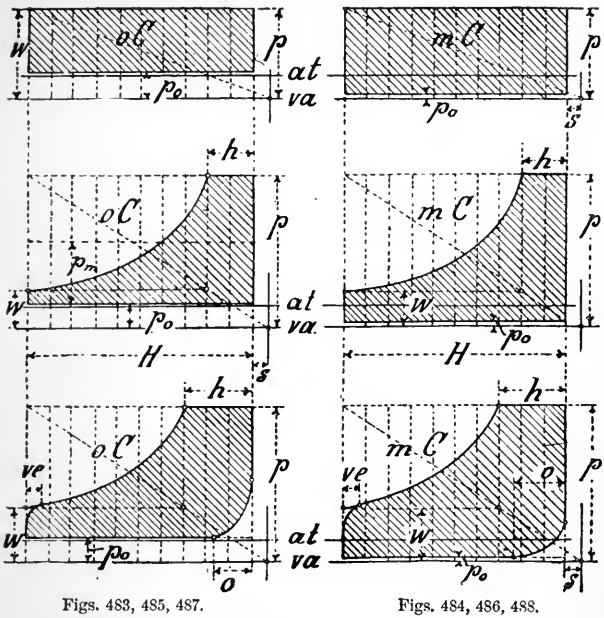
$at$ = the atmospheric line.

$ve$ = the portion of the stroke from the point where the exhaust opens to the end of the stroke; in the diagrams the line $ve$ represents the volume of that portion of the stroke alluded to.

$o$C, diagrams for non-condensing engines.

$m$C, diagrams for condensing engines.

Figs. 483, 484, show the diagram for an engine with steam admitted for the whole stroke and in which the average pressure throughout the whole stroke is equal to the initial pressure—the back pressure




Figs. 483, 485, 487. Figs. 484, 486, 488.

and the diagram is a rectangle; such a case seldom if ever occurs in practice. The figures 485, 486 show imaginary diagrams with steam cut off at ·2 of the stroke; figures 487, 488, show diagrams of a more or less perfect form, with steam cut off at ·3 of the stroke and the corners rounded off as they always come in practice from compression as at *o* and early opening of the exhaust as at *ve*.

The curve formed in these diagrams by the expansion of steam is approximately a rectangular hyperbola, and knowing the initial absolute pressure and the point of cut off, the mean pressure can be calculated by the formula :—

$$p_m = p\left(\frac{1 + \text{hyp. log. R}}{\text{R}}\right)$$

from the value of $p_m$ from this formula the deductions for back pressure, &c., must be made. In the formula R = the ratio of expansion and in the diagrams is the ratio $\frac{\text{H}}{h}$. The approximate expansion curve may be graphically laid down in the following

manner, see figs. 489, 490, which is very convenient for comparing the actual curve formed by the indicator and that which would be formed were the action of the steam unaltered by the condensation which always takes place in the cylinder of a steam engine.

Fig. 489.

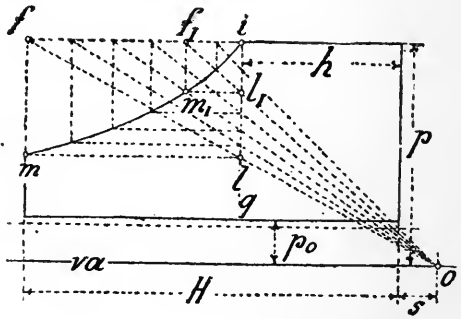
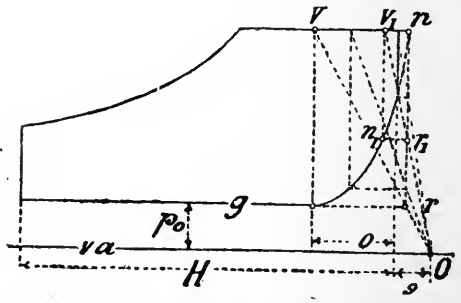



Fig. 490.




H = the length of the diagram and represents the stroke of the piston, and as the cylinder is parallel throughout its length, the line H also represents the volume swept by the piston in making one complete stroke.

$h$ = the period of admission.

$s$ = the clearance expressed in terms of the piston area, so that $s$ in line H represents the volume of the clearance.

$p$ = the initial absolute pressure in lbs. per square inch laid off to any convenient scale.

$va$ = the line of perfect vacuum.

$p_o$ = the back pressure of the exhaust steam.

$o$ = the length of the compression period or the remainder of the stroke left to be completed after the exhaust has closed.

Complete the rectangle on the lines $p$H, then from point O draw

the line $o f$, and the line $i q$ parallel to the line $p$; from the point where $o f$ cuts $i q$ draw $l m$ parallel to H, then $m$ is the terminal point of the curve; the remaining points are found by drawing lines from O to points on the upper side of the rectangle, and the horizontal lines from where they cut the line $i q$, fig. 489.

Fig. 490 shows the same process for drawing the compression curve.

For obtaining the mean pressure on the piston from a diagram thus drawn, it may be either measured by means of a planimeter, or by dividing the figure into equal parts by vertical lines and measuring the sum of the vertical heights of these parts and dividing by their number for the average. Further explanation of these diagrams and their uses will be found at page 373. The above curve does not actually represent the expansion curve, only an approximation; a truer curve may be obtained by Rankine's formula:

$$\text{Pressure} \times (\text{volume})^{\frac{17}{16}} = \text{constant}.$$

If the pressure be expressed in lbs. per square inch, and the volumes in cubic feet, the constant has a value of 475, when adopting Zeuner's modification of Rankine's formula $\text{Pressure} \times (\text{volume})^{1\cdot0646} = 475$ The formula is referring to one pound of steam. The volume occupied by one pound of steam at different pressures is called the specific volume for that pressure.*

The back pressure ($p_o$) of exhaust in lbs. per square inch absolute for a speed of about 80 feet per second is given in the table.

TABLE 52.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Terminal pressure, $w$ = | 8·8 | 11·7 | 14·7 | 17·6 | 22·0 | 29·4 | 44·0 | 58·8 |
| For non-condensing engine, $p_o$ = | — | — | 14·7 | 15·4 | 16·2 | 17·1 | 18·0 | 18·5 |
| For condensing engine, $p_o$ = | 3·23 | 3·7 | 4·1 | 4·4 | 4·7 | 4·9 | 5·3 | 5·6 |

All pressures are given in lbs. per square inch absolute.

For ordinary work $p_o$ may be taken as 17 lbs. absolute for non-condensing engines, and 3·7 for condensing engines.

* See further remarks on p. 446.

### Classification of Valves and Valve Gears.

Valves and valve gears may be divided under the following heads :

A. Gears of simple kind, with eccentrics working either ordinary slide valves or piston valves.

B. Trip valve gears with Corliss valves.

C. Trip or positive motion gears with mushroom valves.

### A. Simple Slide or Piston Valve Gears.

(*a*) With one slide or piston valve, rate of expansion usually fixed ; or when combined with a Hartnell governor or link motion, the rate of expansion is variable.

(*b*) Double slide valve gears, with two separate slide valves ; the expansion or cut-off valve working on the back of the main or exhaust valve, including Meyer's valve gear, Rider's, and others also, in which the expansion valve is controlled by the governor. In these gears both valves are worked by separate eccentrics, with the exception of one or two special examples

### B. Trip Valve Gears with Corliss Valves.

(*a*) Gears in which the valves, such as Corliss valves, are opened positively, and let go at a period determined by the governor, by a so-called "trip" gear, the closing of the valves being effected by springs or dash-pots. The valves are parts of cylinders, and work to and fro in bored-out seatings.

(*b*) Gears in which the Corliss valves revolve continuously, such as those of Siegel and Ehrhardt.

In Corliss valve gears there are usually two steam valves and two exhaust valves. The advantages of this system will be referred to when treating of Corliss engines, pages 252 *et seq.*

### C. Gears with Mushroom Valves.

(*a*) Gears with positively driven valves of mushroom form.

(*b*) Gears with valves driven through the medium of trip gear, the valves being of mushroom form. Examples of these are given on pages 234 *et seq.*

## Slide Valves.

The figures 491—500 show longtitudinal and cross sections of simple slide valves, such as are used in small steam engines.

Fig. 491.

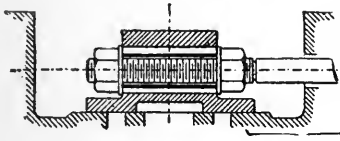
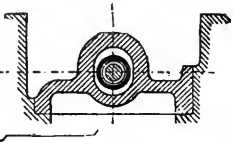


Fig. 492



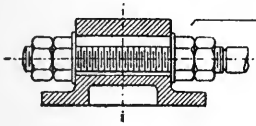


Fig. 493.

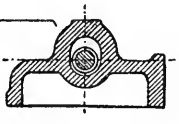
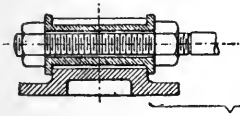


Fig. 494.

Fig. 495.



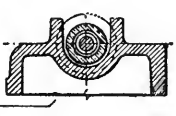


Fig. 496.

Fig. 497.

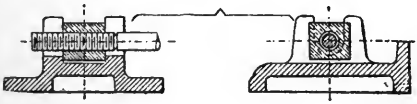


Fig. 498.

Fig. 499.

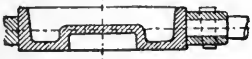
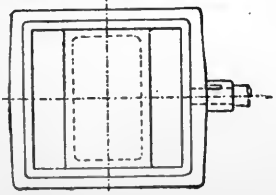


Fig. 500.



Figs. 501—503 show sections of the "Trick" valve, with the double opening for steam shown by the arrows; this is a good form of slide valve for quick running engines. The width of the port, $a = 2c + d$, and the eccentric radius or half stroke, $r = e + 2c$.

Fig. 501. Fig. 502. Fig. 503.

Figs. 504 and 505, show a main and cut-off slide valve, each worked by a separate eccentric, and for a fixed rate of expansion. Only one port is shown in the example given at each end of the main valve, but it is generally better to have a number of ports, 4 to 6, or even more. They are then termed multiple ported, or "gridiron slide valves.

Fig. 504. Fig. 505.

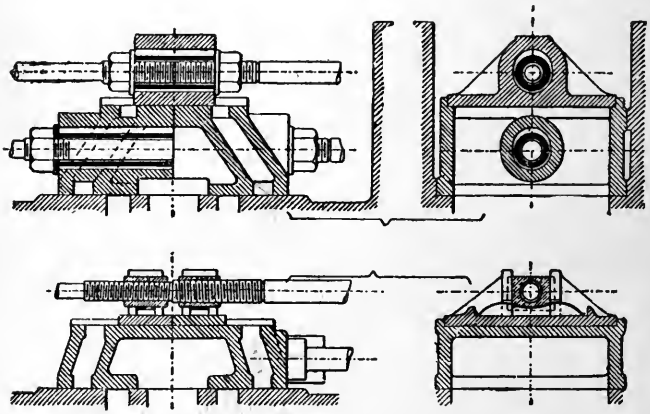


Fig. 506. Fig. 507.

Figs. 506 and 507 show an example of Meyer's valves for variable expansion, in which the cut-off is varied by increasing the distance between the outer edges of the cut-off valve. The valve is in two parts, one part having a right hand nut, the other a left hand, and a corresponding thread cut on the valve spindle, which is capable of being turned round by a hand wheel. or, in some cases, by being actuated by the governor.

In Rider's valve gear, of which the valves are shown in figs. 508—511, the cut-off valve itself corresponds to the right and left hand screw of Meyer's. The rate of expansion is varied by turning the cut-off valve on its seat, which is formed by boring out a recess on

Fig. 508.

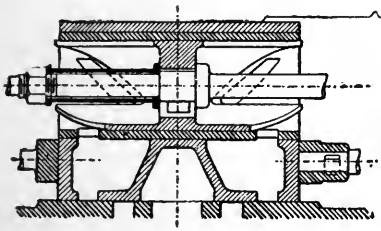
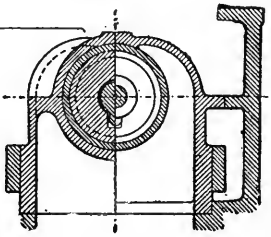


Fig. 509.



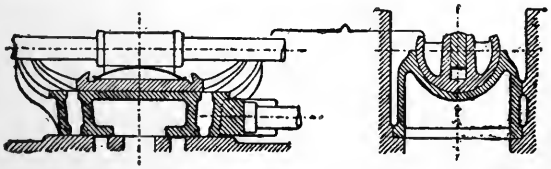


Fig. 510.

Fig. 511.

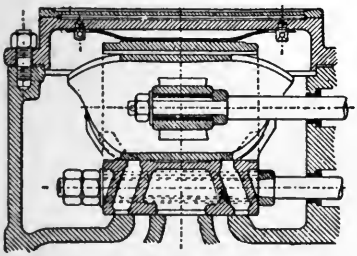


Fig. 512.

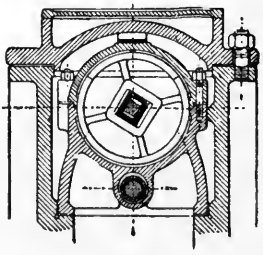


Fig. 513.

the back of the main valve. Fig. 508 gives an example of a closed Rider valve, and fig. 510, an open one; the cut-off valve is usually connected with the governor.

Figs. 512 and 513 give another example of closed Rider valves.

A modification of Rider's valves is shown in figs. 514—516, where in place of the cut-off valve being cylindrical it is flat with inclined edges, and is moved across the back of the main valve by means of a rack and pinion. The figs. are taken from valves by Heinrich Lanz of Mannheim.

Fig. 514.

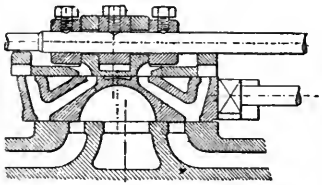
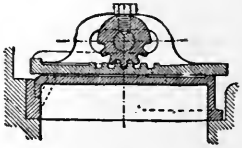


Fig. 515.



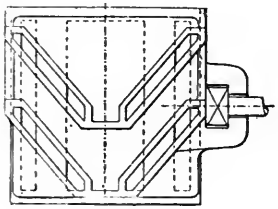


Fig. 516.

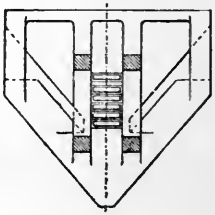


Fig. 517.

An arrangement of valve for a tandem compound portable engine by Messrs. Garrett, Smith & Co., of Buckau-Magdeburg, is shown in fig. 518, the arrows indicating the passage of steam and exhaust.

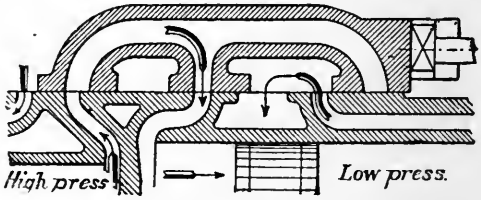



Fig. 518.

The double ported valve, fig. 519, is a form where the two end ports of the main valve are separate. This is necessary where a variation in the cut-off is effected by turning the cut-off valve

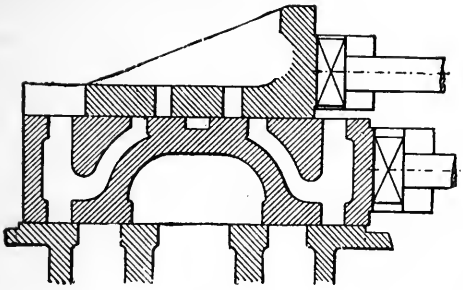


Fig. 519.

eccentric round on the shaft ; in other words, by increasing the angle of advance of the cut-off valve eccentric. When the variation is effected by altering the stroke of the cut-off valve eccentric, the main valve may be a hollow case, with a number of ports at the back, all of which ports will be in use, admitting steam to whichever end of the cylinder the main valve allows it to enter. The advantages of having a number of ports are, that the cut-off is much more rapid than with only one or two ports.

A double slide valve arrangement, fig. 520, has a separate chamber for the expansion valve. There are some advantages in this, and it

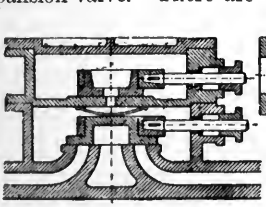


Fig. 520.

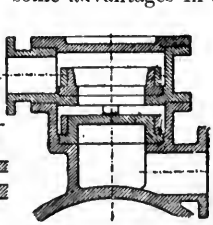


Fig. 521.

has been very successfully used by Messrs. Davey, Paxman & Co., of Colchester.

In order to reduce the stroke of a slide valve, the double ported single valve, figs. 522, 523, was introduced by Messrs. Penn for marine engines : $a$ equalling the total width of the steam passage, then the radius of the eccentric, or half stroke, $r = \cdot 5a + e$. The lead and lap are half the amount which would be required for a simple valve for the same width of port. The steam enters by the passages E E, as well as over the back of the valve.

Fig. 522.

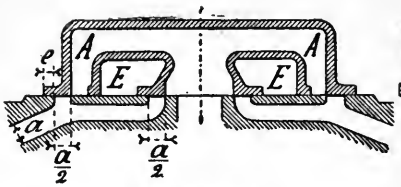
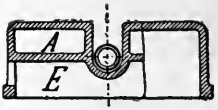



Fig. 523.



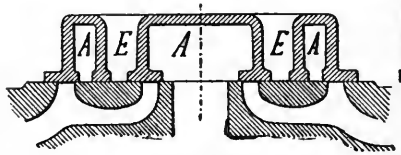




Fig. 524.

Fig. 525.

A variety of Penn's valve, by Borsig, is shown in figs. 524, 525. The passages, A A, are in connection with the side passages, D D, fig. 525. This arrangement allows of an expansion valve to be used on the back of the main valve in the usual way.

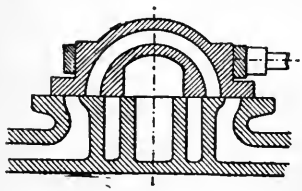


Fig. 526.

Fig. 526 shows the valve of Hick for a compound engine, with both pistons moving in the same direction.

Fig. 527.

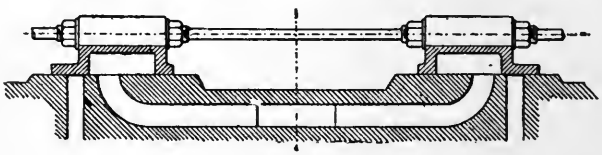
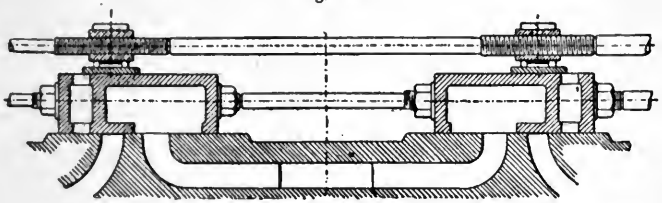


Fig. 528.

In order to reduce the length of the ports to a minimum, valves are often made in two parts, fig. 528. The same effect is produced by the long valve, fig. 527, but is not so good as separating the two ends as in fig. 528. In Meyer's and Rider's valve gears they can be arranged

as in figs. 529, 530, where the two ends are separate, and the ports thus made very short.

Fig. 529.



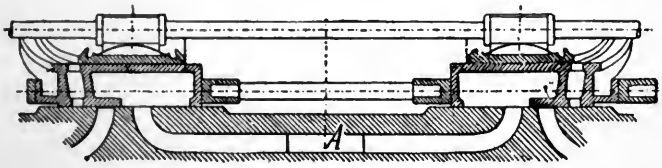



Fig. 530.

The attachment of the valve to the valve rod or spindle, is effected in various ways, and it should always be remembered that the centre line of the rod should be as near the port face as possible, so that the push and pull may be near to the line of greatest resistance, and thus to move the valve as quietly and steadily as possible.

In order to place the rod close to the port face, the rod is often made with a T head, fitting into a recess in the end of valve,

Fig. 531.

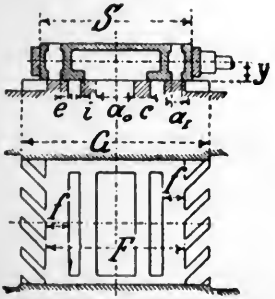



Fig. 532.

$f = a_1 + e + \frac{1}{4}''$.

$G = s + 1{\cdot}5\,r$.

Fig. 533.

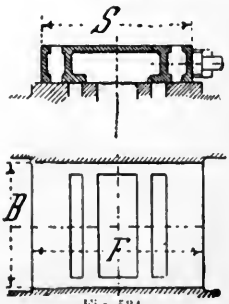



Fig. 534.

$F = s + r$.

fig. 533, or a bridle, figs. 536, 537, is used. Considering the small surface given by these T headed rods, it is somewhat surprising how long they will last without undue slackness from wear.

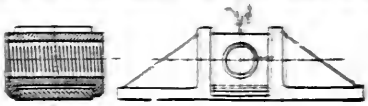
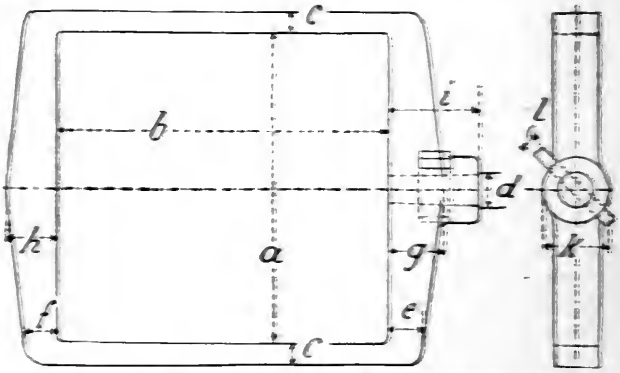


Fig. 535.

Expansion valves are often attached, as shown in fig. 535, by means of a block through which the rod passes, and in the case of Meyer's valves, is screwed into the block, or, with other valves for ordinary work, secured by a cotter.




Figs. 536 and 537.—Valve bridle for valves of the kind shown in fig. 535.

The great pressure exerted by the steam on slide valves has induced many schemes to be brought out to relieve this pressure. To construct a perfect "balanced" slide valve, is a point of great

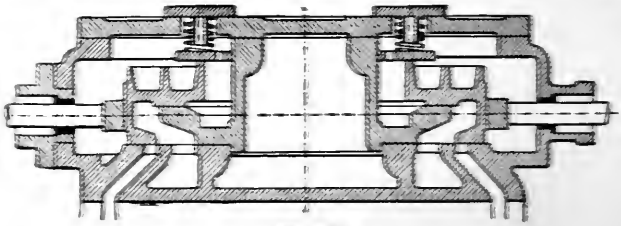


Fig. 538.

difficulty; many so-called balanced valves remaining so for a very short time after the engine has been working. A few examples are shown in figs. 538—541. In fig. 539, the valve is balanced by a ring

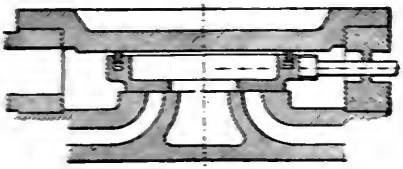


Fig. 539.

on the back, held up by light springs against the cover, so as to prevent the pressure of steam from acting on the back of the valve.

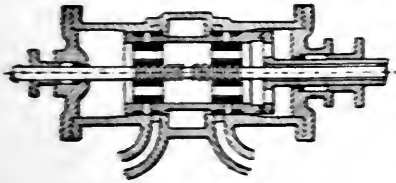


Fig. 540.

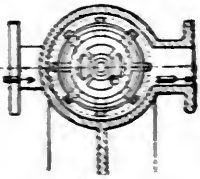


Fig. 541.

Perhaps the best form of balanced valve is the piston valve, which has been successfully used in marine engines with very high pressures. Examples of these will be found on pages 222, 223.

## Simple Valve Gears.

The following reference letters are used throughout the investigations of valve gear diagrams and valves in the next pages 164—204.

$a$. The admission or steam port.

$a_0$. The exhaust port.

$c$. The breadth of the bars between the ports.

$e$. The outside lap.

$i$. The inside lap.

$r$. The radius of the eccentric, or half the stroke of valve.

$v$. The lead or length of steam port open to steam at beginning of stroke.

$v_0$. The inner lead on exhaust side.

The simple valve, worked by an eccentric, is chiefly used in small engines with cut off at from ·5 to ·8 of stroke, much better results being obtained from valve gears with two valves,

worked by separate eccentrics. A single valve, however, attached to a link motion, has been used as a variable expansion apparatus, as well as for reversing.

Single valves in combination with a Hartnell governor, figs. 474, 476, page 145, have given good results,* the action on the valve being nearly the same in this case as with the link motion. Simple slide valves with the reference letters are shown in figs. 542 and 543.

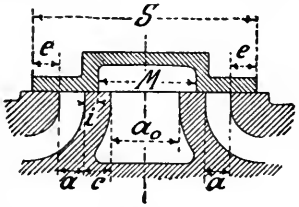



Fig. 542.

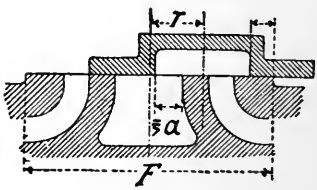



Fig. 543.

The proportions for given rates of expansion are :—

| For cut off at ·5 | at ·6 | at ·7 |
|---|---|---|
| $e = 2\,a$ | $e = 1{\cdot}3\,a$ | $e = {\cdot}8\,a$ |
| $i = {\cdot}7\,a$ | $i = {\cdot}5\,a$ | $i = {\cdot}3\,a$ |
| $r = {\cdot}8\,a + e$ | $r = a + e$ | $r = a + e$ |
| $v = {\cdot}25\,a$ to $0{\cdot}5\,a$ | $v = {\cdot}2\,a$ to ·4 $a$ | $v = {\cdot}2\,a$ to ·3 $a$. |

The greater values of $v$ are for quick running.

Figs. 544—547 show in diagram the relative positions of the crank and valve in a simple valve gear, at four different points in the stroke.

In fig. 544 the piston is at the left hand end, and crank is at the beginning of the stroke, or, at the dead point; the steam port is open to the extent of the lead $v$, the exhaust port is open $v_0$; $x = e + v$.

In fig. 545 the steam port is full open, and the valve, at its extreme position, to the right; $x = r$.

In fig. 546 the steam port is closed and the expansion has begun; $x = e$.

In fig. 547 the exhaust is closed, and the compression has begun; $x = i$.

In these figures, K is the crank, $\delta$, the angular advance of the eccentric radius E, and the arrows show the direction of running, and the direction of the flow of steam in the ports and passages.

* See report of judges at the Cardiff Meeting of the Royal Agricultural Society.

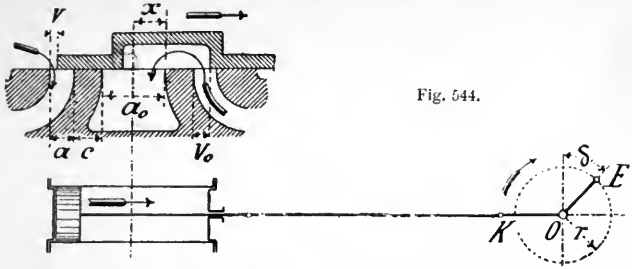



Fig. 544.

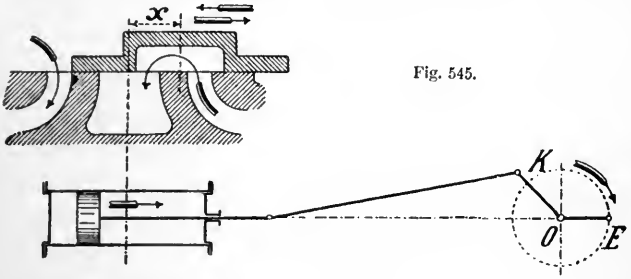



Fig. 545.

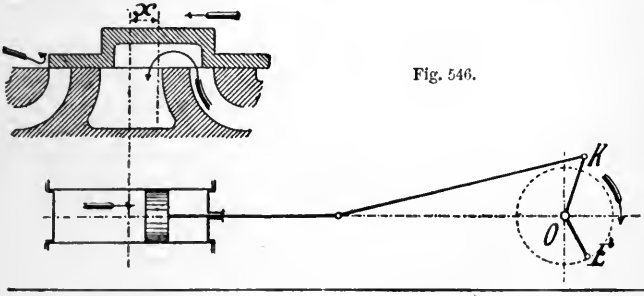



Fig. 546.

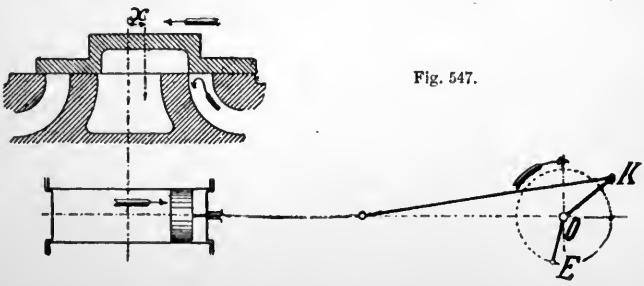



Fig. 547.

### Zeuner's Valve Diagram.

By means of Zeuner's valve diagram, the relative positions of crank and valve can be shown graphically; the construction is briefly as follows: Draw the two axes at right angles to each other, O X, O Y, figs. 548, 549, then make O E = $e$ = the outside lap; E V = $v$ = the lead; with radius = $\frac{r}{2}$ describe the circle O V G cutting O and V, then M will be the centre of this circle, called the valve circle, O G will = $r$, and will give the position of the eccentric radius,

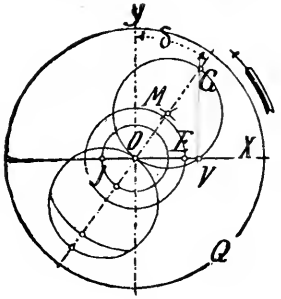



Fig. 548.

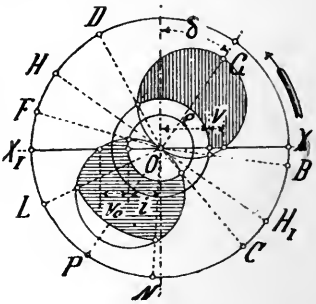



Fig. 549.

and δ will be the angle of advance on O G produced. A circle of the same radius is then drawn below O X. Make O J = $i$ the inside lap, and draw the crank circle from centre O of any convenient size. Note that in this diagram the crank moves in the direction of the arrow the contrary way to that in which the engine crank moves.

Looking at fig. 549, when the crank is at—

O B, the steam port is beginning to open at right hand.

O X, the right hand steam port is open to the extent of the lead $v$ (crank at dead point to the right hand).

O G, valve at its furthest position to the left.

O D, the right hand steam port closes and expansion begins.

O H, valve in its middle position.

O F, beginning of exhaust at the right hand.

O $X_1$, exhaust port open $v_0$ at the right hand (crank at dead point to the left hand).

O P, valve at its furthest position to the right.

O L to O N, exhaust open fully to right hand.

O C, exhaust closes, beginning of compression.

O $H_1$, valve in its middle position.

From P to G (in direction of arrow), through $H_1$, the valve moves to the left. From G to P, through H, the valve moves to the right.

The half stroke or radius of eccentricity equals the port + the lap.

$$r = a + e\ ;\ \text{but } r \text{ can be } \lessgtr a + e.$$

Fig. 550.

$r < a + e = a_1 + e$

$a = 12$

$a_1 = 10$

$e = 18$

$i = 7$

$v = 4$

$r = 10 + 18 = 28$

Fig. 551.

$r > a + e = a + e + m$

$a = 12$

$m = 2$

$e = 18$

$i = 7$

$v = 4$

$r = 12 + 18 + 2 = 32$

Fig. 550.

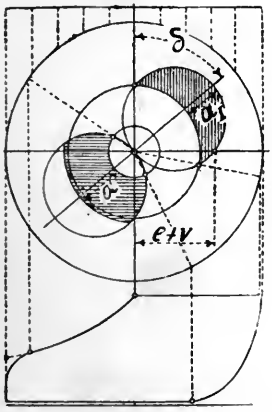
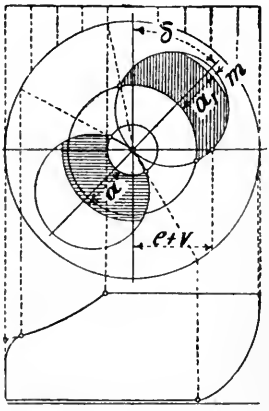



Fig. 551.



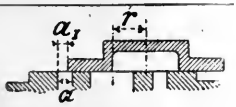




Fig. 552.

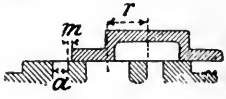



Fig. 553.

The point of cut off will be earlier with the shorter stroke, and it is often sufficient that the greatest opening of port to steam $a_1 = \cdot 8\, a$. This smaller opening of port to steam, takes place in the single valve gears connected with a governor of the Hartnell type, in order to keep the range of the governor as short as possible, and can be arranged to give very good admission and exhaust, as the exhaust side of the valve allows of full opening of the port.

Figs. 554 and 555.

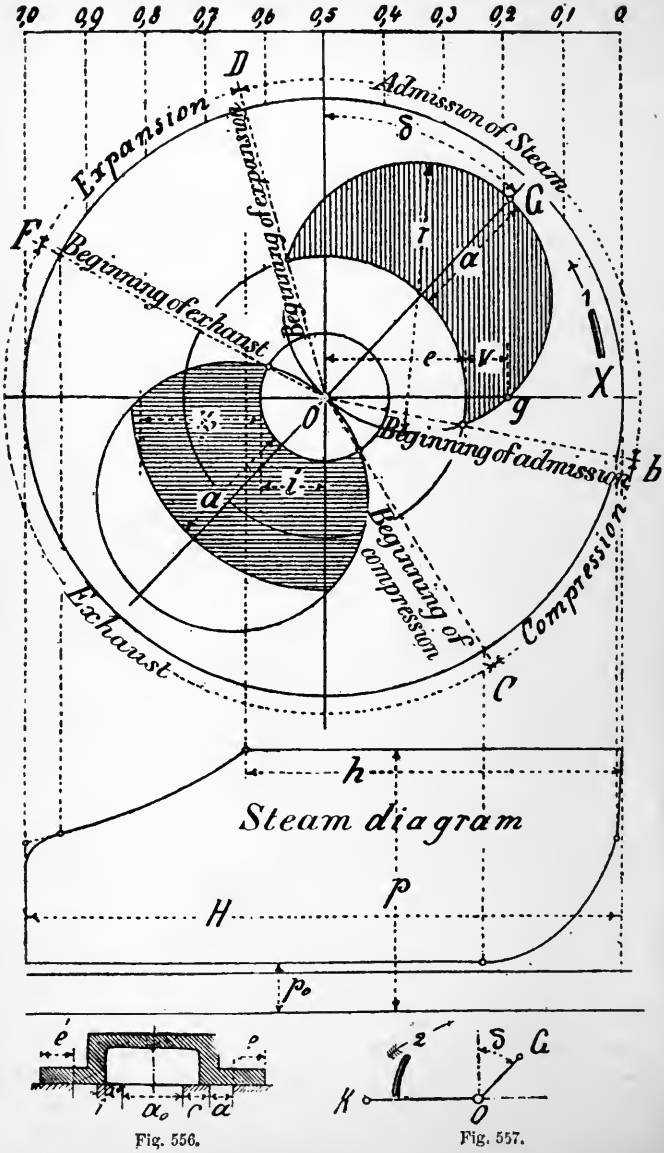



Fig. 556. Fig. 557.

### Valve Diagram for a Simple Valve Gear.

O X, direction of valve motion.
O, centre of the diagram.
$e$, outside lap (circle 2 $e$ diameter about centre O, called lap circle).
$i$, inside lap (circle 2 $i$ diameter about centre O).
$v$, lead of the valve, O $g = e + v$.
$r = a + e$ the radius or half stroke of the eccentric (valve circle through $g$ and O).
H, diameter of the crank circle (any convenient size)

Then in figures 554 to 557—

$v_0$ = inner or exhaust lead.
O G, position of the eccentric radius.
$\delta$ = the angle of advance.
O B, the position of the crank for beginning of admission.
O D, „ „ „ of expansion.
O F, „ „ „ of exhaust.
O C, „ „ „ of compression.
$h$ = the position of cut off.

If there is no inside lap, then the beginning of compression and exhaust take place on a line at right angles to the original position of the eccentric radius.

The diagram crank moves in the direction of the arrow 1, in fig. 554 ; the engine crank moves in the direction of the arrow 2, in fig. 557 ; the radius of the eccentric is in advance of the crank to the extent of $90° + \delta$ ; O K is the position of the crank, O G that of the eccentric, fig. 557. In order to understand this valve diagram, it is better to draw the steam diagram under, as shown in fig. 555.

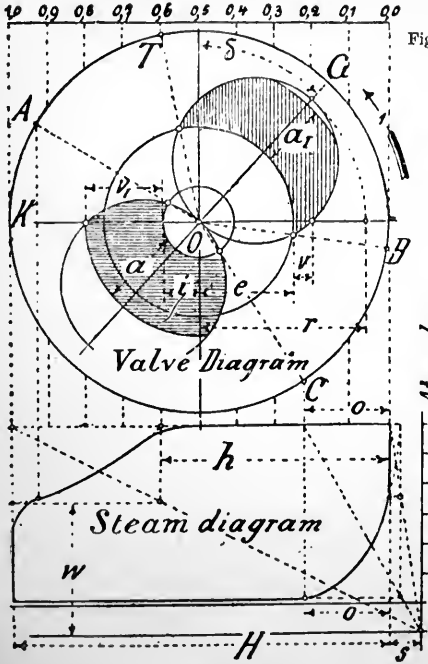
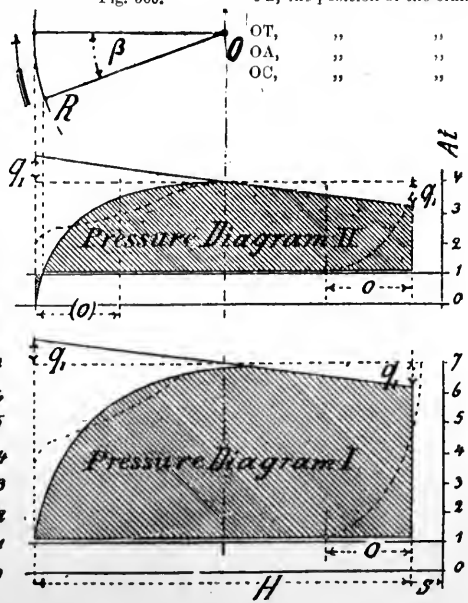



Fig. 559.

Fig. 558.

Fig. 560.



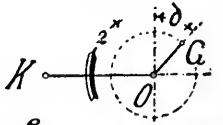

## Valve Diagram (Fig. 558).

OB, the position of the crank when valve begins to open the steam port.
OT, ,, ,, ,, closes the steam port.
OA, ,, ,, ,, opens exhaust.
OC, ,, ,, ,, closes exhaust.

## Pressure Diagrams I. and II.

$q_3$, the centrifugal force of the reciprocating parts of the engine expressed in terms of the piston area taken at the dead point, and with an infinitely long connecting rod.

Fig. 561.



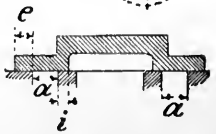




Fig. 562.

Arrow 1, fig. 558, direction of movement of the diagram crank.
Arrow 2, fig. 561, direction of movement of the engine crank.

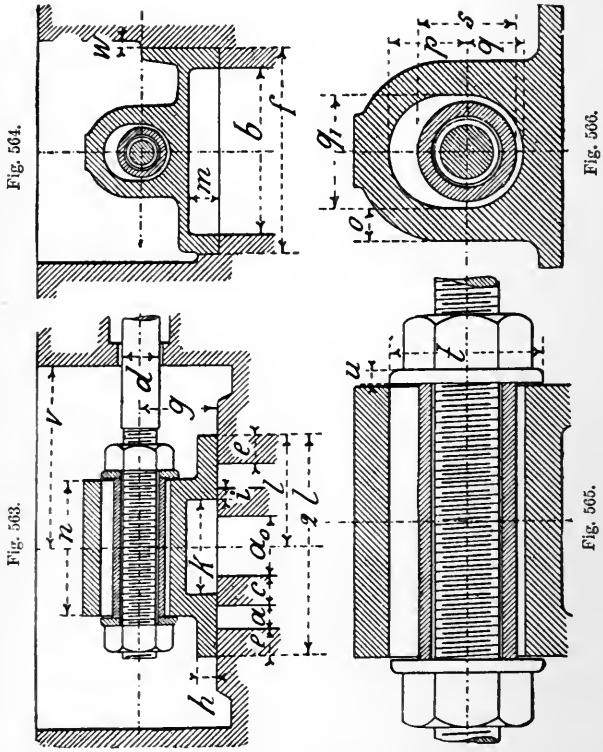
TABLE 53.—**Valve Diagram for Simple Valve Gear** (Fig. 558).

| | | | | | | |
|---|---|---|---|---|---|---|
| Stroke | H | 12 | 16 | 20 | 24 | 28 |
| Diameter of piston | D | 6 | 8 | 10 | 12 | 14 |
| Revolutions per minute | $n$ | 125 | 110 | 100 | 90 | 85 |
| Width of steam ports in port face | $a$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 |
| Necessary width of opening to steam | $a_1$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{13}{16}$ |
| Outside lap | $e$ | $\frac{7}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ |
| Inside lap | $i$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{7}{16}$ |
| Radius of eccentric | $r$ | $\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ |
| Lead, outer | $v$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ |
| Lead, inner | $v_1$ | $\frac{5}{16}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{15}{16}$ |
| Cut off | $h$ | ·6 | ·6 | ·6 | ·6 | ·6 |
| Exhaust | $f$ | ·07 | ·07 | ·07 | ·07 | ·06 |
| Compression | $o$ | ·2 | ·2 | ·2 | ·2 | ·2 |
| Angle of advance in degrees | $\delta$ | 42 | 41 | 41 | 41 | 41 |

All Dimensions are given in Inches.

From the pressure diagram I it will be seen that with 7 atmospheres absolute pressure and full load the direction of pressure in the connecting rod changes at the dead point, but with 4 atmospheres absolute pressure, diagram II, it changes before the dead point at O R, angle $\beta$.

## Slide Valves.




The above figures show a simple slide valve corresponding to the valve diagram, fig. 558, and a table of dimensions is given on next page.

TABLE 54.—**Dimensions of Simple Slide Valve** (Figs. 563—566, and for Valve Diagram, see Fig. 558).

| Engine. | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | $a_0$ | $a$ | $b$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ | $m$ | $n$ | $o$ | $p$ | $q$ | $q_1$ | $s$ | $t$ | $u$ | $v$ | $w$ | $r$ |
| 12 | 6 | $\frac{3}{4}$ | $\frac{3}{8}$ | $3\frac{1}{4}$ | $\frac{9}{16}$ | $\frac{7}{8}$ | $\frac{7}{16}$ | $4\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{3}{16}$ | $1\frac{5}{8}$ | $1\frac{13}{16}$ | $\frac{5}{8}$ | $2\frac{1}{2}$ | $\frac{3}{8}$ | 1 | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{3}{16}$ | 3 | $\frac{3}{16}$ | $\frac{3}{4}$ |
| 16 | 8 | $1\frac{1}{8}$ | $\frac{1}{2}$ | $4\frac{3}{8}$ | $\frac{5}{8}$ | 1 | $\frac{5}{8}$ | $5\frac{3}{8}$ | 2 | $\frac{1}{2}$ | $\frac{1}{4}$ | 2 | $2\frac{3}{8}$ | $\frac{5}{8}$ | $2\frac{3}{4}$ | $\frac{1}{2}$ | 1 | $\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | 2 | $\frac{3}{16}$ | $3\frac{3}{4}$ | $\frac{3}{16}$ | $1\frac{1}{8}$ |
| 20 | 10 | $1\frac{1}{2}$ | $\frac{5}{8}$ | $5\frac{5}{8}$ | $\frac{11}{16}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | $6\frac{3}{4}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{5}{16}$ | $2\frac{3}{8}$ | $2\frac{7}{8}$ | $\frac{3}{4}$ | $3\frac{1}{2}$ | $\frac{5}{8}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | $1\frac{7}{8}$ | $1\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{3}{16}$ | $4\frac{5}{8}$ | $\frac{3}{16}$ | $1\frac{3}{8}$ |
| 24 | 12 | $2\frac{1}{8}$ | $\frac{3}{4}$ | $6\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{3}{16}$ | 1 | $8\frac{3}{8}$ | $2\frac{3}{8}$ | $\frac{11}{16}$ | $\frac{3}{8}$ | $2\frac{7}{8}$ | $3\frac{9}{16}$ | 1 | $4\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | 1 | $1\frac{7}{8}$ | $1\frac{5}{8}$ | $2\frac{5}{8}$ | $\frac{1}{4}$ | 6 | $\frac{5}{16}$ | $1\frac{3}{4}$ |
| 28 | 14 | $2\frac{3}{8}$ | 1 | $8\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | 10 | $2\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $3\frac{3}{4}$ | $4\frac{9}{16}$ | $1\frac{1}{4}$ | 5 | $\frac{3}{4}$ | $1\frac{1}{4}$ | 1 | $1\frac{7}{8}$ | $1\frac{5}{8}$ | $2\frac{3}{4}$ | $\frac{1}{4}$ | $7\frac{1}{4}$ | $\frac{5}{16}$ | $2\frac{1}{4}$ |

All Dimensions are given in Inches.

## Valve Gears with Two Valves.

### Meyer's Valve Gear.

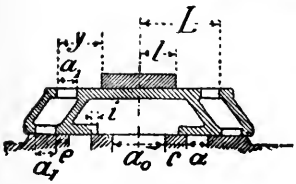



Fig 567.

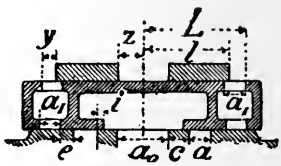



Fig. 568.

Fig. 567 shows the two valves arranged for a fixed rate of expansion; fig. 568 for variable expansion, with the following reference letters.

$a$, width of steam ports in port face.
$a_1$, width of steam ports in main valve.
$a_0$, width of exhaust port.
$c$, width of bars between ports.
$e$, outside lap.
$i$, inside lap.
$v$, outside lead.
$v_0$, inside lead or exhaust lead.
$r$, half stroke of main valve.
$r_1$, half stroke of cut-off valve.
$\delta$, angle of advance of main valve eccentric.
$\delta_1$, angle of advance of cut-off valve eccentric.
$y = L - l$, distance between working edges of valves; in fig. 568 an ideal middle position is taken for any selected point of cut off.
$z$, the horizontal distance from centre line of the back edge of cut-off valve for any selected point of cut off.

I, the valve circle of main valve, fig. 569.
II, the valve circle of cut-off valve.
III, the relative valve circle.

Valve diagram, fig. 569.

The outside lap circle, $2e$ diameter.

The inside lap circle, $2i$ diameter.

The valve circle I, with a diameter of O G $= r =$ half stroke of main valve, is drawn the same as for the simple valve gear. The advance angle of the cut-off valve eccentric $\delta_1$ may be taken from 60° to 90°, and the cut-off valve circle II described with

diameter O E = $r_1$ = half stroke of cut-off valve eccentric. Draw G P parallel to O E, and O P parallel to E G, then O P will be the diameter of the relative valve circle III. The chord of valve circle III gives the distance between the centres of the two valves which is greatest when the crank is in the position O P, and then is equal to the line O P; for a fixed period of admission or point of cut off, for example ·7, O S = L − $l$, and the shaded part of the diagram shows the opening of the port to steam. When the crank is at O N, the port in the main valve is fully open; when at O $m$, the port is

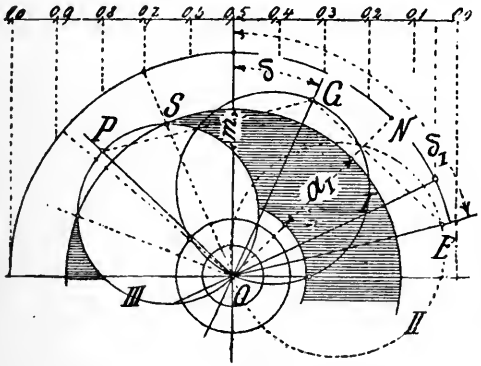



Fig. 569.

open to the extent of $m$; when at O S, the port is closed: the greater the distance between the working edges of the cut-off plates or valves, the greater is $l$, and so L − $l$ is less. For very early cut off, L − $l$ is negative; example, for a cut off at ·05, the crank centre line cuts the circle III in the lower quadrant.

Fig. 570.

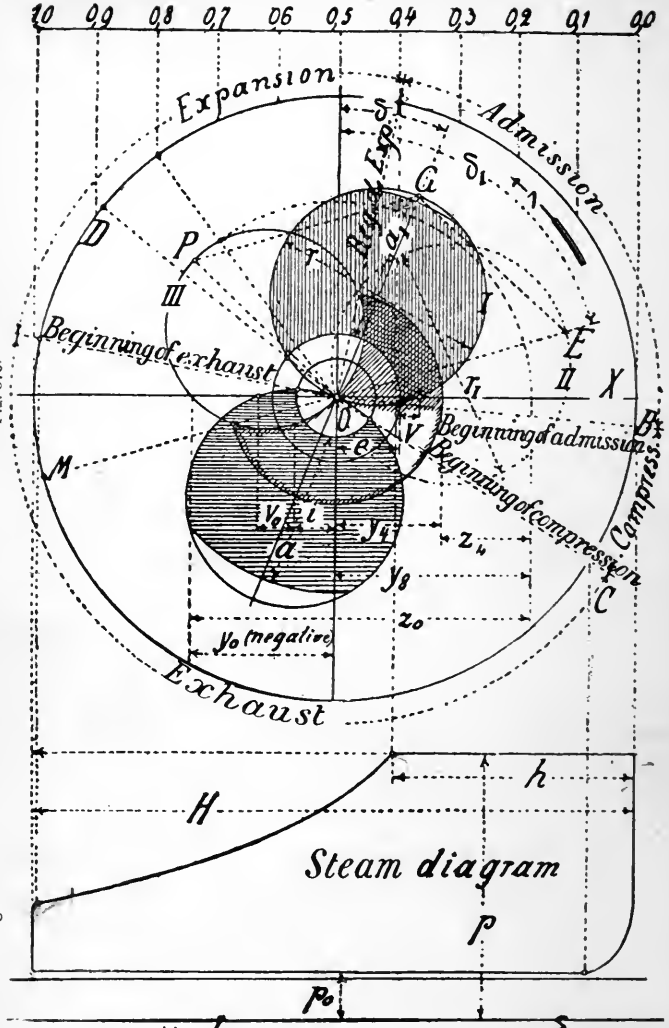



Fig. 571.




Figs. 572 and 573.

**Valve Diagram for Meyer's Valve Gear** (Figs. 570—573).

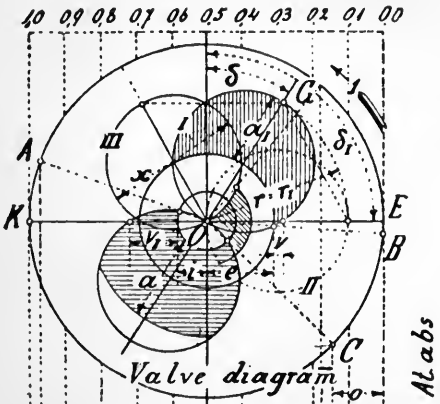
O X, direction of the valve motion, that is, plane of port face.
$e$, outside lap.
$i$, inside lap.
$v$, lead.
$r$, half stroke of main valve eccentric.
O E, position of cut-off valve eccentric radius.
$r_1$ half stroke of cut-off valve eccentric.
G $P_1$, parallel to O E.
O $P_1$, diameter of relative or resultant valve circle.
$V_o$, inside lead.
$\delta$, angle of advance of main valve eccentric.
$\delta_1$, angle of advance of cut-off valve eccentric.
$y_8 = L - l$, for cut-off at ·8 ; chord of circle III.
$y_4 = L - l$, for cut-off at ·4 ; chord of circle III.
$y_0 = L - l$, for cut-off at ·0 ; chord of circle III., negative.
·8 is taken as the latest cut-off.

O B, position of crank for beginning of admission.
O, ·4 „ „ for beginning of expansion for cut-off at ·4.
O D, „ „ when main valve closes the steam port.
O F, „ „ when exhaust opens.
O M, „ „ when port in main valve reopens to steam for cut off at ·4.
O C, „ „ when exhaust closes and compression begins.

The chord of valve circle I. gives the distance of the middle of the main valve from the centre of the port face.

The chord of valve circle II. gives the distance of the middle of the cut-off valve from the centre of the port face.

The chord of the valve circle III. gives the distance between the centres of the two valves.




Figs. 574 and 575.

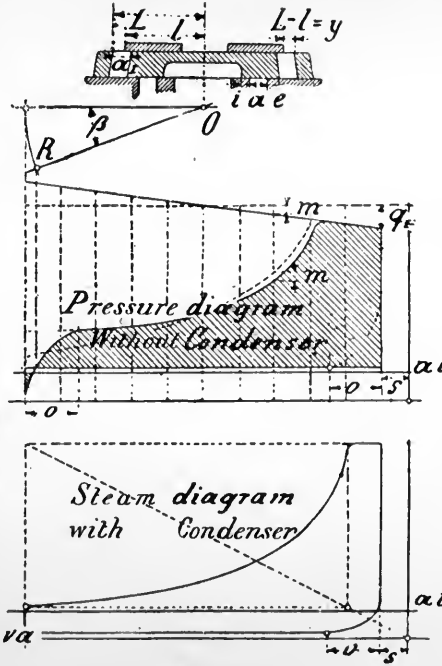



Fig. 576—578.

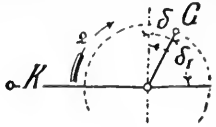



Fig. 579.

OK, position of crank.
OG, „ of main valve eccentric.
OE, „ of cut-off valve eccentric.

**Valve Diagram.**

OB, beginning of admission
OA, „ of exhaust.
OC, „ of compression.

Arrow 1, direction of movement of diagram crank.

Arrow 2, direction of movement of engine crank.

TABLE 55.—**Valve Diagram for Meyer's Valve Gear** (Figs. 574—578).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stroke | H | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
| Diameter of piston | D | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| Revolutions per minute | $n$ | 110 | 100 | 90 | 85 | 80 | 78 | 75 | 72 |
| Width of steam ports | $a$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ |
| Width of ports in main valve | $a_1$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| Outside lap | $e$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| Inside lap | $i$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{5}{8}$ |
| Half stroke of both valves | $r=r_1$ | $\frac{3}{4}$ | 1 | $1\frac{5}{16}$ | $1\frac{5}{8}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ |
| Lead, outside | $v$ | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ |
| Lead, inside | $v_1$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | $\frac{7}{8}$ |
| Angle of advance, main valve eccentric in degrees | $\delta$ | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 |
| Angle of advance, cut-off eccentric in degrees | $\delta_1$ | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| Greatest distance between both valves | $x$ | $\frac{3}{4}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ |
| The variable distance $L-l$ between the working edges, $y$, is for different points of cut-off: cut-off at ·73 | $y$ | $\frac{3}{4}$ | $\frac{15}{16}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ |
| ,, ·60 | $y$ | $\frac{11}{16}$ | $\frac{7}{8}$ | $1\frac{3}{16}$ | $1\frac{5}{16}$ | $1\frac{13}{16}$ | $2\frac{1}{8}$ | $2\frac{5}{16}$ | $2\frac{5}{8}$ |
| ,, ·50 | $y$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{1}{16}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $2\frac{1}{8}$ | $2\frac{3}{8}$ |
| ,, ·40 | $y$ | $\frac{9}{16}$ | $\frac{11}{16}$ | $\frac{15}{16}$ | $1\frac{3}{16}$ | $1\frac{7}{16}$ | $1\frac{1}{4}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ |
| ,, ·30 | $y$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{16}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ |
| ,, ·20 | $y$ | $\frac{7}{16}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ |
| ,, ·10 | $y$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ | $\frac{3}{8}$ |
| ,, ·00 | $y$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |

All Dimensions are given in Inches.

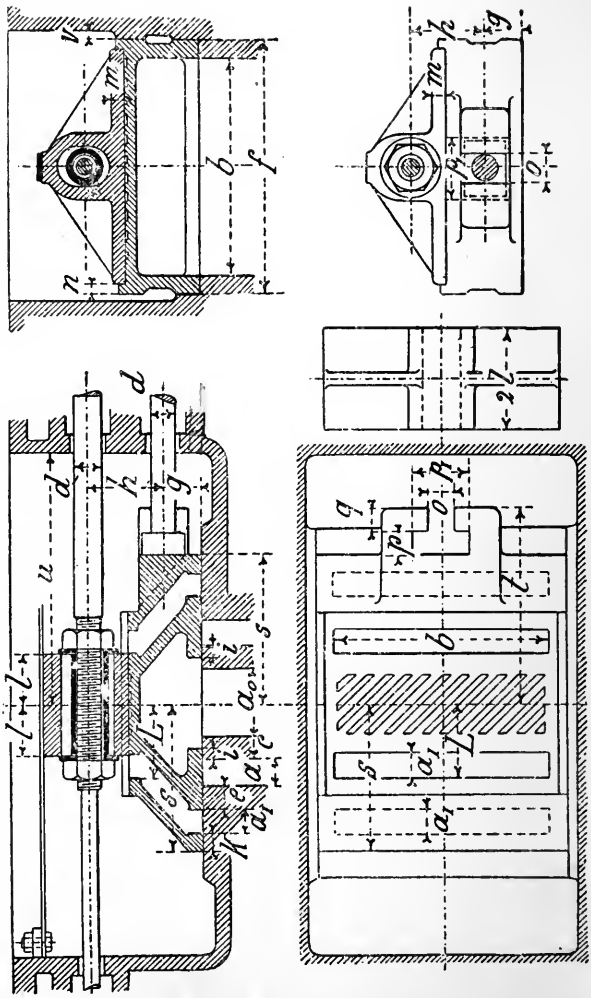


Fig. 580.

Fig. 581.

Fig. 582.

Fig. 583.

TABLE 56.—**Double Valves, for Fixed Expansion** (Figs. 580—583).

| H | D | $a_0$ | $a$ | $a_1$ | $b$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $m$ | $n$ | $o$ | $p$ | $p_1$ | $q$ | $s$ | $t$ | $u$ | $v$ | $r=r_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 8 | 1 | $\frac{1}{2}$ | $\frac{3}{8}$ | $4\frac{3}{8}$ | $\frac{5}{8}$ | 1 | $\frac{3}{8}$ | $5\frac{3}{8}$ | 1 | 3 | $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $2\frac{1}{4}$ | $\frac{3}{4}$ | 3 | $4\frac{3}{8}$ | $5\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{4}$ |
| 20 | 10 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $5\frac{5}{8}$ | $\frac{11}{16}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ | $6\frac{3}{4}$ | $1\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $\frac{11}{16}$ | $2\frac{3}{8}$ | $\frac{7}{8}$ | $3\frac{5}{8}$ | $5\frac{3}{16}$ | $6\frac{5}{8}$ | $\frac{1}{4}$ | 1 |
| 24 | 12 | $1\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $6\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $8\frac{3}{8}$ | $1\frac{3}{8}$ | $3\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{5}{8}$ | 1 | $4\frac{3}{8}$ | $6\frac{1}{8}$ | 8 | $\frac{3}{8}$ | $1\frac{5}{16}$ |
| 28 | 14 | $2\frac{3}{8}$ | 1 | $\frac{7}{8}$ | $8\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | 10 | $1\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | 1 | $5\frac{5}{16}$ | $7\frac{3}{16}$ | $9\frac{1}{4}$ | $\frac{3}{8}$ | $1\frac{5}{8}$ |
| 32 | 16 | $2\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | 10 | 1 | $1\frac{3}{8}$ | $\frac{7}{8}$ | $11\frac{5}{8}$ | $1\frac{3}{4}$ | $3\frac{3}{4}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | 1 | 3 | $1\frac{1}{8}$ | $6\frac{1}{8}$ | $8\frac{1}{4}$ | $10\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{7}{8}$ |
| 36 | 18 | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $11\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | 1 | $13\frac{3}{8}$ | $1\frac{3}{4}$ | 4 | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $1\frac{5}{8}$ | 1 | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $6\frac{13}{16}$ | $9\frac{1}{16}$ | 12 | $\frac{3}{8}$ | $2\frac{1}{8}$ |
| 40 | 20 | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $13\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $15\frac{1}{4}$ | 2 | $4\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{7}{8}$ | $1\frac{1}{8}$ | $3\frac{3}{8}$ | $1\frac{3}{8}$ | $7\frac{15}{16}$ | $10\frac{7}{16}$ | $13\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{2}$ |
| 44 | 22 | 4 | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $14\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $1\frac{1}{4}$ | $16\frac{3}{4}$ | $2\frac{1}{4}$ | $4\frac{3}{8}$ | $\frac{5}{8}$ | 1 | $\frac{3}{4}$ | $\frac{1}{2}$ | 2 | $1\frac{1}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $8\frac{5}{8}$ | $11\frac{3}{8}$ | 15 | $\frac{3}{8}$ | $2\frac{3}{4}$ |

All Dimensions are given in Inches

Fig. 584.

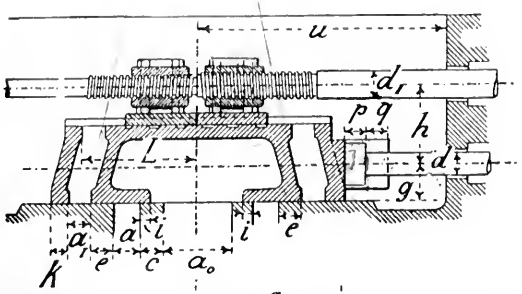



Fig. 585.

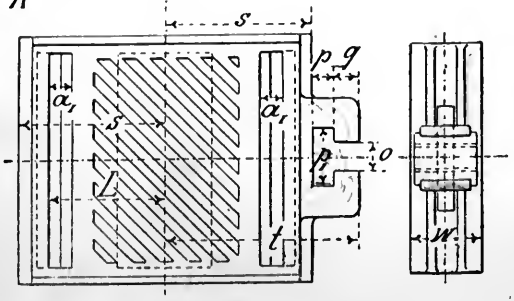



Fig. 586.

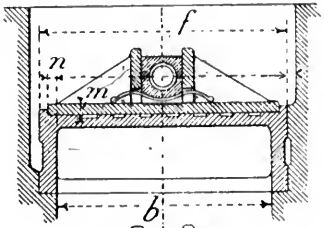



Fig. 587.

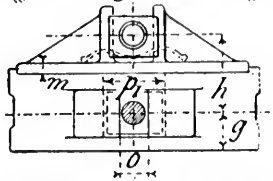
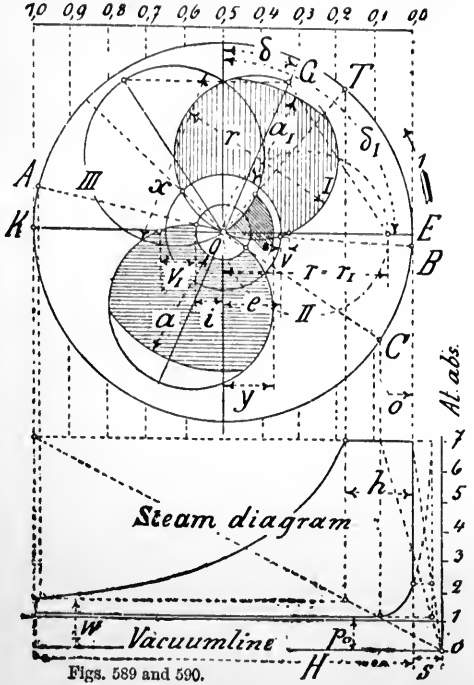



Fig. 588.

TABLE 57.—**Valves for Meyer's Variable Expansion Gear** (Figs. 584—588).

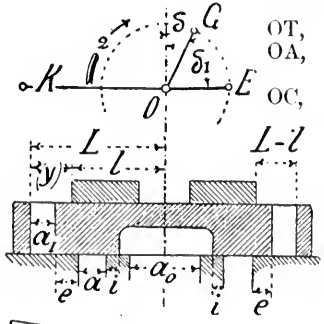
| H | D | $a_0$ | $a$ | $a_1$ | $b$ | $c$ | $d$ | $d_1$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $m$ | $n$ | $o$ | $p$ | $p_1$ | $q$ | $s$ | $t$ | $u$ | $v$ | $r=r_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 8 | 1 | $\frac{1}{2}$ | $\frac{3}{8}$ | $4\frac{3}{8}$ | $\frac{5}{8}$ | 1 | $1\frac{3}{16}$ | $\frac{3}{8}$ | $5\frac{3}{8}$ | 1 | 3 | $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $2\frac{1}{4}$ | $\frac{3}{4}$ | 3 | $4\frac{3}{8}$ | $5\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{4}$ |
| 20 | 10 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $5\frac{5}{8}$ | $\frac{11}{16}$ | $1\frac{1}{8}$ | $1\frac{5}{16}$ | $\frac{1}{2}$ | $6\frac{3}{4}$ | $1\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{5}{16}$ | $1\frac{1}{4}$ | $\frac{11}{16}$ | $2\frac{3}{8}$ | $\frac{7}{8}$ | $3\frac{5}{8}$ | $5\frac{3}{16}$ | $6\frac{5}{8}$ | $\frac{1}{4}$ | 1 |
| 24 | 12 | $1\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $6\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | $8\frac{3}{8}$ | $1\frac{3}{8}$ | $3\frac{3}{8}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{5}{8}$ | 1 | $4\frac{3}{8}$ | $6\frac{1}{8}$ | 8 | $\frac{3}{8}$ | $1\frac{5}{16}$ |
| 28 | 14 | $2\frac{3}{8}$ | 1 | $\frac{7}{8}$ | $8\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | 10 | $1\frac{5}{8}$ | $3\frac{5}{8}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | 1 | $5\frac{5}{16}$ | $7\frac{3}{16}$ | $9\frac{1}{4}$ | $\frac{3}{8}$ | $1\frac{5}{8}$ |
| 32 | 16 | $2\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | 10 | 1 | $1\frac{3}{8}$ | $1\frac{5}{8}$ | $\frac{7}{8}$ | $11\frac{5}{8}$ | $1\frac{7}{4}$ | $3\frac{7}{8}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | 1 | 3 | $1\frac{1}{8}$ | $6\frac{1}{8}$ | $8\frac{1}{4}$ | $10\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{7}{8}$ |
| 36 | 18 | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $11\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | 1 | $13\frac{3}{8}$ | $1\frac{3}{4}$ | $4\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $1\frac{5}{8}$ | 1 | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $6\frac{13}{16}$ | $9\frac{1}{16}$ | 12 | $\frac{3}{8}$ | $2\frac{1}{8}$ |
| 40 | 20 | $3\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $13\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 | $1\frac{1}{8}$ | $15\frac{1}{4}$ | 2 | $4\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{7}{8}$ | $1\frac{1}{8}$ | $3\frac{3}{8}$ | $1\frac{3}{8}$ | $7\frac{15}{16}$ | $10\frac{7}{16}$ | $13\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{2}$ |
| 44 | 22 | 4 | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $14\frac{7}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $1\frac{1}{4}$ | $16\frac{3}{4}$ | $2\frac{1}{4}$ | $4\frac{5}{8}$ | $\frac{5}{8}$ | 1 | $\frac{7}{8}$ | $\frac{1}{2}$ | 2 | $1\frac{1}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $8\frac{5}{8}$ | $11\frac{3}{8}$ | 15 | $\frac{3}{8}$ | $2\frac{3}{4}$ |

All Dimensions are given in Inches.



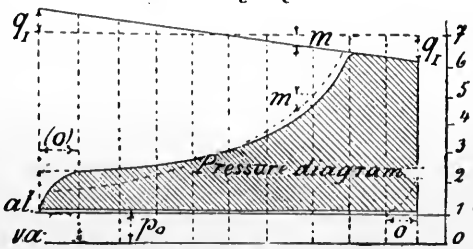

Figs. 589 and 590.

OK, position of crank (figs. 589, 591).
OG, „ of main valve eccentric.
OE, „ of cut-off valve eccentric.
OB, position of crank at beginning of admission.
OT, „ „ at cut-off, $h$.
OA, „ „ at beginning of exhaust.
OC, „ „ at beginning of compression.




**Pressure Diagram** (fig. 593).

$q_1$ is the centrifugal force of the reciprocating parts expressed in terms of the piston area at the dead point with indefinitely long connecting-rod.




Figs. 591—593.

Arrow 1, fig. 589, the direction of the movement of the diagram crank.

Arrow 2, fig. 591, the direction of the movement of the engine crank.

TABLE 58.—**Diagram of Expansion Valves for Small Clearance Space** (Figs. 589—593).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stroke . . . . . H | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
| Diameter of piston . . . . . D | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| Revolutions per minute . . . . . $n$ | 110 | 100 | 90 | 85 | 80 | 78 | 75 | 72 |
| Width of port in port face . . . . . $a$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ |
| „ „ in main valve . . . . . $a_1$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| Outside lap . . . . . $e$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{13}{16}$ |
| Inside lap . . . . . $i$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{3}{8}$ |
| Half stroke of both valves . . . . $r=r_1$ | $\frac{3}{4}$ | 1 | $1\frac{3}{16}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ | $2\frac{7}{16}$ |
| Lead outside . . . . . $v$ | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{1}{4}$ |
| „ inside . . . . . $v_1$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{11}{16}$ |
| Angle of advance, main valve eccentric in degrees $\delta$ | 26 | 26 | 25 | 24 | 24 | 25 | 25 | 25 |
| „ „ cut-off in degrees . . $\delta_1$ | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| Greatest distance between valves . . . $x$ | $\frac{3}{4}$ | $1\frac{1}{16}$ | $1\frac{5}{16}$ | $1\frac{9}{16}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ | $2\frac{7}{16}$ | $2\frac{11}{16}$ |
| Variable distance L—$l$ between the working edges of the valves, $y$, in the diagram for different points of cut-off . ·76 . . . $y$ | $\frac{3}{4}$ | $1\frac{1}{16}$ | $1\frac{5}{16}$ | $1\frac{9}{16}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ | $2\frac{7}{16}$ | $2\frac{11}{16}$ |
| ·60 . . . $y$ | $\frac{11}{16}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{1}{4}$ | $2\frac{1}{2}$ |
| ·50 . . . $y$ | $\frac{5}{8}$ | $\frac{7}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 | $2\frac{5}{16}$ |
| ·40 . . . $y$ | $\frac{1}{2}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | 2 |
| ·30 . . . $y$ | $\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| ·20 . . . $y$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{9}{16}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | 1 |
| ·10 . . . $y$ | $\frac{1}{16}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{3}{16}$ |
| ·00 . . . $y$ | $-\frac{3}{8}$ | $-\frac{1}{2}$ | $-\frac{5}{8}$ | $-\frac{7}{8}$ | $-1$ | $-1\frac{1}{8}$ | $-1\frac{1}{4}$ | $-1\frac{5}{8}$ |

All Dimensions are given in Inches.

## The Valve Ellipse.

### (a.) For Simple Valve Gear.

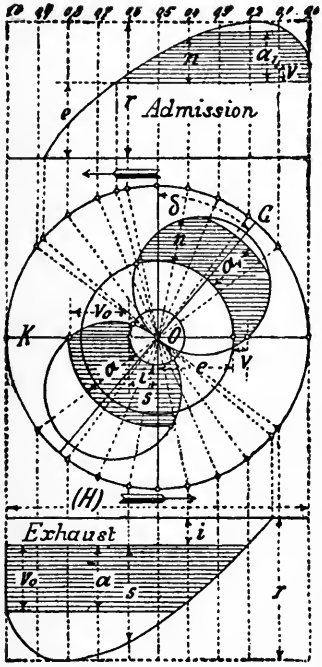



Fig. 594.

The valve ellipse, fig. 594, is a great assistance in understanding Zeuner's valve diagram, and it also shows the speed with which the valve moves at different parts of its stroke, when opening or closing the ports. The length of the connecting-rod is disregarded and is taken to be infinite. The diameter of the crank circle is divided in 10 equal parts, and perpendicular lines are drawn through these points terminating in horizontal lines as in the fig. 594 placed for convenience above and below the valve diagram, and the distances from the centre of the valve to the centre of the port face (chords of the valve circle) are laid off on the perpendicular lines, through the points thus found the curve called the valve ellipse is drawn, the lap $e$ is laid off and the port width $a_1$, then the shaded part of the diagram gives the actual opening of the port by the valve; at the dead point, for example, the port is open to the extent of $v$, when the crank is at the position ·4 the port is open the amount $n$. The scale of fig. 594 is $\frac{2}{5}$ natural size:

Width of port, $a_1$ = ·67 inch.
„ $a$ = ·78 „
Half stroke of valve $r$ = 1·77 inch.
Lap (outside) $e$ = ·98 „
„ (inside) $i$ = ·35 „
Lead (outside) $v$ = ·196 inch.
„ (inside) $v_o$ = ·78 „
Angle of advance $\delta$ = 41°.

### (b.) For Rider's and Meyer's Valve Gears.

The diagram and ellipse for the main slide is constructed in the same manner as for the simple valve gear. In the figs. 595, 596, the influence of the magnitude of the angle of advance $\delta_1$ (of the cut-off

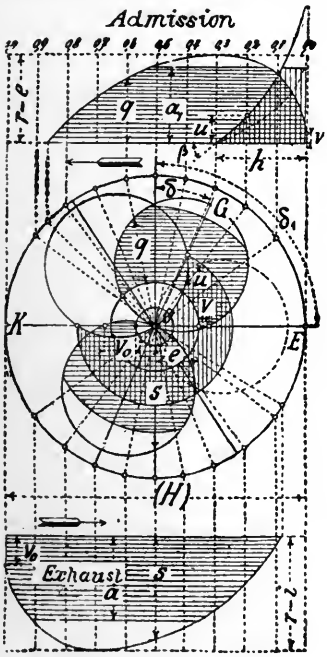



Fig. 595.

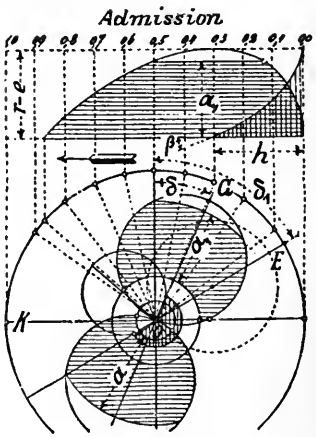



Fig. 596.

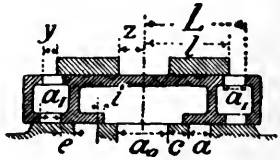



Fig. 597.

valve eccentric) on the speed with which the ports are closed is shown, and the following data are taken as starting points :—

Admission period or cut-off, $h$ = ·3 port in back of main valve $a_1$ = ·98 inch ; steam port, $a$ = 1·14 inch ; outside lap, $e$ = ·59 inch ; inside lap, $i$ = 2·55 inch ; half stroke of main and cut-off valves $r$ and $r_1$ = 1·73 inch ; outside lead = ·12 inch angle of advance of main valve eccentric = 24° scale $\frac{3}{5}$ natural size. In fig. 595 the advance angle of cut-off valve eccentric = 90°, in fig. 596 = 60°. To show the opening of the ports in back of main valve, lay off the distances between the acting edges of the main and cut-off valves as

ordinates, then the area shaded with vertical lines gives the opening of the ports, a comparison of fig. 595 with fig. 596 shows there is a better admission of steam with an advance angle of 90° than with 60° ; the magnitude of the angle $\beta$ shows this clearly.

### Defect in Arrangement of Valve Gears.

By defective arrangement of valve gears with two valves worked by separate eccentrics, a second admission of steam may take place towards the end of the stroke before the main valve has closed the steam port. The diagram fig. 598 shows an example of this, the ex-

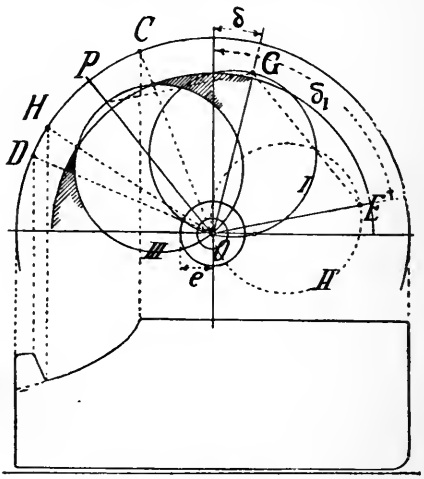



Fig. 598.

pansion will begin when the crank is at O C when the cut-off valve has closed the port ; but they will reopen again when the crank is at O H, and second admission will take place as the main valve only closes the port when the crank is at O D. This fault can be avoided by a proper advance angle $\delta_1$ and stroke of valve 2 $r_1$, the position of the diameter O P of the valve circle III. fig. 598 must be near the position O D the point at which the main valve closes the port. To avoid this fault requires great care in valve gears where the expansion is varied by varying the stroke of the cut-off valve eccentric as in Hartnell's expansion governor. Under indicator diagrams will be found an example which occurred in practice, but from a different cause to that above mentioned.

**Arrangement for Variation of Expansion by Band.**

The expansion may be varied by increasing the advance angle of the cut-off eccentric by turning the eccentric round on the shaft and fixing it by means of a bolt to the main valve eccentric as shown in fig. 599, this has usually to be adjusted when the engine is stopped, but it has also been arranged to be varied automatically. The diagram fig. 600 shows the effect of altering the advance angle $\delta_1$ from 90° to 60° and the cut will be thus altered from ·6 to ·25 of the stroke. It should be noted that for this kind of variable expansion the two ends of the main valve must be separated from each other as in fig. 584, so that each end is independent, but for valve gears where the

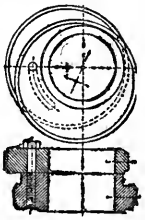


Fig. 599.

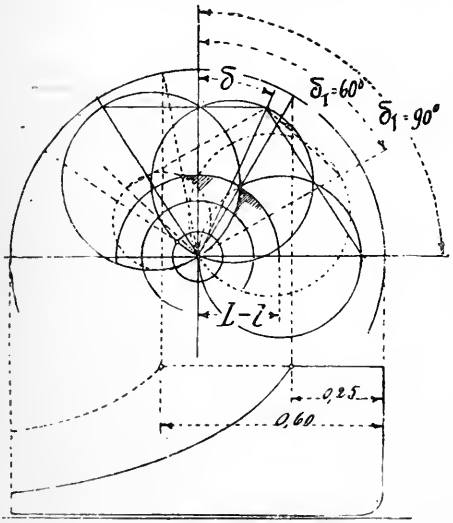



Fig. 600.

$a = 29$ ; $e = 15$ ; $r = 44$ ; $v = 3$.
$a_1 = 25$ ; $i = 6{\cdot}5$ ; $r_1 = 44$ ; $L - l = 22$.
Angle of advance $\delta_1 = 90°$ ; Cut off = 0·25.
,, ,, ,, $= 60°$ ; ,, = 0·60.

expansion is varied by altering the stroke of the cut-off eccentric the two ends need not be independent of each other, so that all the ports in the back of the main valve are used for each end of the cylinder.

## Valve Diagram for Valve Gears with Two Slide Valves, each Worked by a Separate Eccentric.

The construction of the diagram is as follows:—

First describe a circle (fig. 601) whose diameter equals the stroke of the main valve eccentric and draw the horizontal and vertical diameters, R Q = N T. On the horizontal, R Q set off the lap of the valve, plus the lead, O L; from O L erect a perpendicular, cutting the circle VI. in K, draw the radial line, O K, then O K will be the position of the main valve eccentric radius when the crank is at one of the dead points R, and the angle K O N, will be the "angle of advance" of main eccentric. The steam port in cylinder may be represented by the perpendiculars drawn below R Q from the points P and J, the distance O P being equal to the lap of the valve. If now the radial line O K be imagined to move round on the centre O, in the direction of the arrow VI. from K to the point $K_1$, it will show the angular movement of the crank-pin and eccentric radius from the dead point of the former until the valve has returned and closed the port. If the distance K $K_1$ is taken with the compasses and set off from R to $x_0$ in circle VI. and a perpendicular dropped cutting R Q in $x_2$, the proportion of R $x_2$ to the diameter of the circle VI. will give the portion of the piston-stroke during which steam is admitted. It is easy to follow this motion and obtain the position of the crank, and from thence the position of the piston for the admission, cut-off, release and compression, by setting out the steam ports and exhaust in their proper position at the right of the port P J; and by setting out the valve on a separate piece of paper and moving it backwards and forwards along the line R Q, and holding a set-square against the left-hand edge of the valve so as to mark the different phases on the circle or on the diameter R Q, all the positions of the piston may be marked on R Q for admission, cut-off, release and compression, and if R Q be divided into tenths, the percentage of stroke may be read off; always bearing in mind that no account in this kind of valve diagram is taken of the difference in the distribution of steam caused by the angle of the connecting and eccentric rods.

For valve gears with two valves, having the cut-off valve worked on the back of the main valve by a separate eccentric, a further construction is necessary. The example given is one with a "gridiron" or many-ported cut-off valve, and with a varying stroke, the maximum stroke being taken as equal to the stroke of the main valve.

On K in the circle VI., describe a circle XII. of a diameter equal

to the width ot one port in back of main valve, and touching this circle, draw the perpendiculars C D, F G. On a point in circle VI. describe a circle equal in diameter, to width of one port in cut-off valve, so that this circle overlaps the line of port in main valve F G, by a small amount, say, $\frac{1}{16}$th of an inch, more or less; this may be called the lead of cut-off valve. The line O A, gives the position of the cut-off

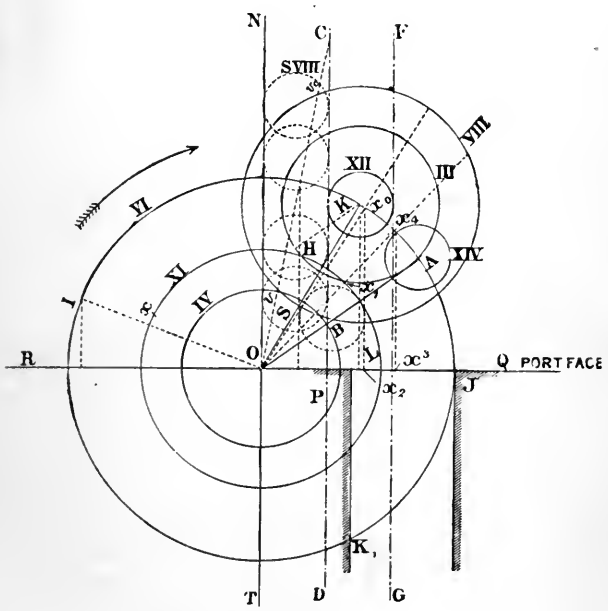



Fig. 601.

eccentric radius, when the crank is at one of the dead points R, and angle N O A "angle of advance" of cut-off valve eccentric.

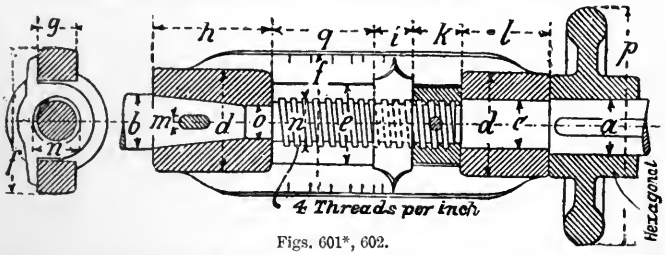
From point K at radius K A, draw circle III. If closely observed, it will be seen that when the system of circles XII. and XIV. are revolved round on centre O, at radius O K, and at the fixed distance from each other K A, they will assume different positions with regard to the observer looking down on them. In the position on the diagram, circle XIV. is below and to the right of

circle XII. and when K reaches $K_1$, XIV. will be to the left of XII. and above it, so in the complete revolution, the two circles XII. and XIV. will revolve about one another, and their relative motion with regard to each other will be the same if one, say, XII., is fixed, and XIV. revolving round it at radius K A, and, taking this to be the case, all the positions of the cut-off valve ports with relation to those on the back of the main valve can be determined; and, further, the position of crank at admission by cut-off valve, at cut-off, and at reopening of main valve ports, can be laid out in percentages of stroke or otherwise.

Describe the circle IV. on centre O at radius equal to K A, then, taking radius of port circle XIV. in compasses, describe circle at H on circle III. touching the line C D. The radius K H will represent position of cut-off eccentric radius when cut-off valve has closed ports on back of main valve, that is, when steam is cut-off; the distance A H will show the angular movement from beginning of stroke to point of cut-off by cut-off valve. Transfer this distance to circle IV. and draw the radius O V cutting the circle VI. at V, drop a perpendicular from V on to R Q and read off percentage of stroke. In the present case of an expansion gear controlled by the stroke of the cut-off valve being decreased or increased by the governor or other means, this will be the latest cut-off corresponding here to the maximum stroke of the cut-off valve. For the earliest cut-off, let circle XIV. be moved along line O A and take the position B giving a shorter stroke to cut-off eccentric, describe the circle VIII. with radius K B on centre K, and describe a circle XI. with same radius on centre O. As before, take radius of port circle and describe circle S with its centre on circle VIII. and touching the line C D; the distance from B to S will give angular movement from beginning of stroke to point of cut-off, transfer this movement to circle XI. From centre O to I draw radial line O I and drop perpendicular from $I_1$ to R Q and read off percentage of stroke. In valve gears where the cut-off is varied by shortening the stroke of cut-off valve eccentric, there is a danger of the ports reopening too soon and admitting steam again late in the stroke before the lap of the main valve has covered the steam port. To find where reopening occurs, describe port circle S VIII. with centre on circle VIII. and touching line C D, transfer the angular motion from B to S VIII. to circle XI. as before, starting on line R Q and cutting the circle XI. at $x_1$. Draw radial line O $x_1$ cutting circle VI. in $x_4$, drop perpendicular on the line R Q, note where it cuts at $x_3$, then if $x_4$ is on the right hand of L, the point where the main valve closes the port, the reopening of cut-off

ports will then take place after the main valve has closed the steam port, and no second admission of steam will take place; if, however, $x_3$ is on the left hand side of L, second admission will take place, and the arrangement will have to be altered. Further, the bars of metal between cut-off ports can be taken from the greatest distance between the main and cut-off eccentric centres, that is, in this case, from K to B, so that the radius of circle VIII. will give the greatest relative movement of the valves on each other and the least possible distance between nearest edges of ports; about $\frac{1}{8}$th of an inch or more must be added in practice for safety.

## Hand Adjustments for Meyer's Valve Gear.




Figs. 601*, 602.

TABLE 59.—**Dimensions of Hand Adjustments for Meyer's Valve Gear** (Figs. 601*, 602).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 8 | 1 | 1⅛ | 1 | 1⅞ | 1½ | 2¾ | ¾ | 2⅜ | ¾ | 1 | 1⅝ | ¼ | 1 | 11/16 | 4⅞ | 1⅛ |
| 20 | 10 | 1⅛ | 1¼ | 1 | 2⅛ | 1½ | 3 | ¾ | 2½ | ¾ | 1 | 1¾ | ¼ | 1 | ¾ | 5¼ | 1⅜ |
| 24 | 12 | 1¼ | 1 5/16 | 1 | 2¼ | 1⅝ | 3¼ | ⅞ | 2½ | ¾ | 1 | 2 | 5/16 | 1 | ¾ | 5½ | 1¾ |
| 28 | 14 | 1¼ | 1⅜ | 1⅛ | 2⅜ | 1¾ | 3⅜ | 1 | 2⅝ | ⅞ | 1⅛ | 2⅛ | ⅜ | 1⅛ | ¾ | 5¾ | 2 1/16 |
| 32 | 16 | 1⅜ | 1½ | 1¼ | 2½ | 2 | 3⅝ | 1 | 2⅞ | 1 | 1¼ | 2¼ | ⅜ | 1¼ | 1 | 6⅜ | 2⅝ |
| 36 | 18 | 1⅜ | 1½ | 1⅜ | 2⅝ | 2⅛ | 3¾ | 1⅛ | 3¼ | 1 | 1⅜ | 2⅜ | ⅜ | 1¼ | 1 | 6¾ | 2½ |
| 40 | 20 | 1½ | 1⅝ | 1⅜ | 2¾ | 2¼ | 4¼ | 1¼ | 3⅝ | 1⅛ | 1⅜ | 2½ | 7/16 | 1⅜ | 1⅛ | 7⅛ | 2⅝ |
| 44 | 22 | 1⅝ | 1¾ | 1½ | 2⅞ | 2⅜ | 4½ | 1¼ | 4 | 1¼ | 1½ | 2¾ | ½ | 1⅜ | 1¼ | 7⅜ | 3 |

All Dimensions are given in Inches.

In the above design (fig. 601*) the hand-wheel is rather small; the boss is therefore made hexagonal, so that a spanner may be used if required.

* $q$ is for cut-off varying from 0 to ·73.

## Hand Adjustment for Meyer's and Rider's Valve Gears.

Fig. 603.

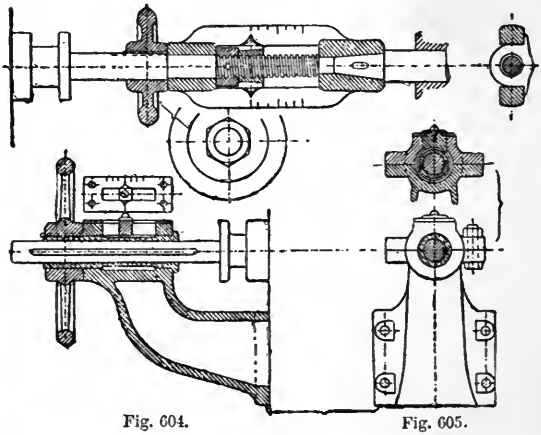


Fig. 604. Fig. 605.

Fig. 606. Fig. 607.

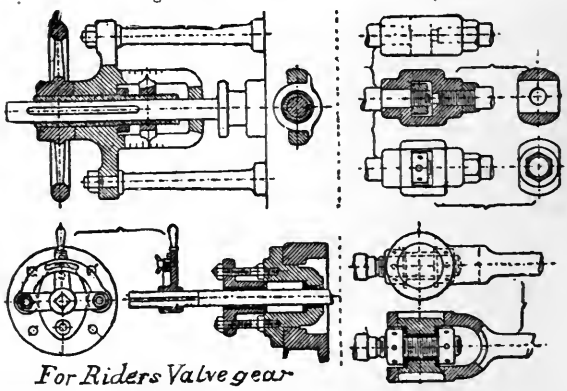



Fig. 608. Fig. 609.

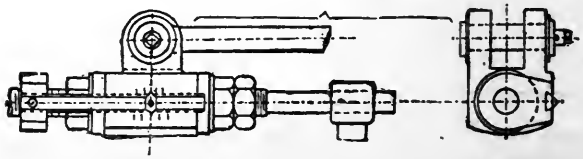
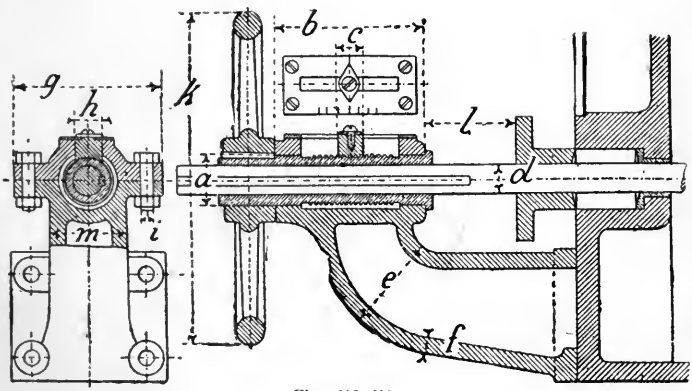


Fig. 610. Fig. 611.

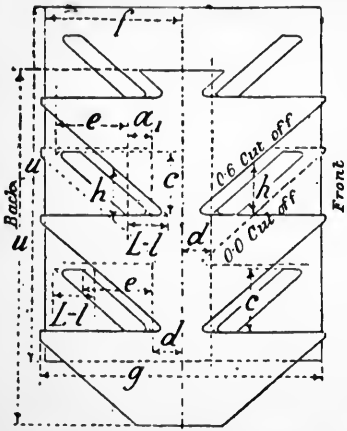



Figs. 612, 613.

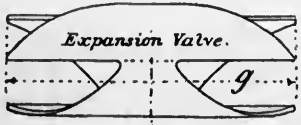
TABLE 60.—**Dimensions of Hand Adjustment for Meyer's Valve Gear** (Figs. 612, 613).

| H | D | *d* | *a* | *b* | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 10 | $\frac{3}{4}$ | $1\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{3}{4}$ | 2 | $\frac{3}{8}$ | 4 | 1 | $\frac{3}{8}$ | 6 | 2 | $1\frac{1}{2}$ |
| 24 | 12 | $\frac{7}{8}$ | $1\frac{3}{8}$ | $3\frac{3}{4}$ | $\frac{7}{8}$ | $2\frac{3}{8}$ | $\frac{3}{8}$ | $4\frac{3}{8}$ | 1 | $\frac{1}{2}$ | $7\frac{5}{8}$ | $2\frac{5}{8}$ | $1\frac{7}{8}$ |
| 28 | 14 | 1 | $1\frac{1}{2}$ | $4\frac{3}{8}$ | 1 | $2\frac{3}{4}$ | $\frac{3}{8}$ | $4\frac{3}{4}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ | $9\frac{1}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{4}$ |
| 32 | 16 | $1\frac{1}{8}$ | $1\frac{3}{4}$ | 5 | $1\frac{1}{8}$ | $3\frac{1}{4}$ | $\frac{1}{2}$ | $5\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $11\frac{1}{4}$ | $3\frac{1}{4}$ | $2\frac{1}{2}$ |
| 36 | 18 | $1\frac{1}{4}$ | $1\frac{7}{8}$ | $5\frac{5}{8}$ | $1\frac{1}{4}$ | $3\frac{5}{8}$ | $\frac{9}{16}$ | $5\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $12\frac{3}{4}$ | $3\frac{5}{8}$ | $2\frac{7}{8}$ |
| 40 | 20 | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $6\frac{3}{8}$ | $1\frac{1}{4}$ | $4\frac{1}{4}$ | $\frac{5}{8}$ | 6 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $14\frac{3}{8}$ | 4 | $3\frac{1}{4}$ |
| 44 | 22 | $1\frac{3}{8}$ | $2\frac{1}{4}$ | $7\frac{1}{4}$ | $1\frac{3}{8}$ | $4\frac{3}{4}$ | $\frac{3}{4}$ | $6\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{5}{8}$ | 16 | $4\frac{3}{8}$ | $3\frac{5}{8}$ |

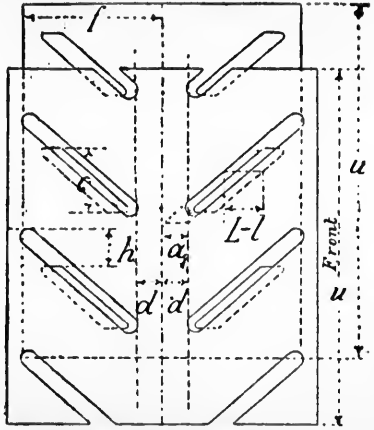
All Dimensions are given in Inches.




*Expansion Valve face rolled out flat.*

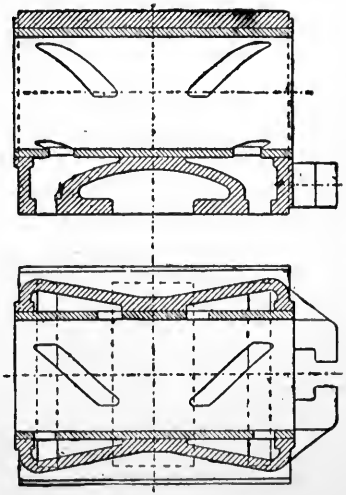



Figs. 614, 615.




*Expansion Valve face rolled out flat.*

Figs. 616, 617.



Figs. 618, 619.

TABLE 61.—**Dimensions of Cut-off Valve Faces, &c., for Rider's Valve Gear** (Figs. 614—619).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stroke | $H$ | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
| Diameter of piston | $D$ | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| Diameter of expansion valve | $m$ | $3\frac{1}{4}$ | 4 | $4\frac{3}{4}$ | $5\frac{5}{8}$ | $6\frac{5}{8}$ | $7\frac{3}{8}$ | $8\frac{3}{8}$ |
| Circumference of expansion valve | $u$ | $10\frac{3}{16}$ | $12\frac{1}{2}$ | $14\frac{7}{8}$ | $17\frac{5}{8}$ | $20\frac{3}{4}$ | $23\frac{1}{16}$ | $26\frac{3}{16}$ |
| $L-l$ for ·0 cut-off | | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ |
| $L-l$ for ·6 cut-off | | $\frac{7}{8}$ | $1\frac{3}{16}$ | $1\frac{5}{16}$ | $1\frac{13}{16}$ | $2\frac{1}{8}$ | $2\frac{5}{16}$ | $2\frac{5}{8}$ |
| Width of port | $a_1$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ |
| Width of port | $b$ | $5\frac{5}{8}$ | $6\frac{3}{4}$ | $8\frac{3}{8}$ | 10 | $11\frac{5}{8}$ | $13\frac{1}{4}$ | $14\frac{3}{4}$ |
| Height of port ($c$=about $\frac{b}{3}$) | $c$ | $1\frac{3}{4}$ | $2\frac{5}{16}$ | $2\frac{3}{4}$ | $3\frac{3}{8}$ | 4 | $4\frac{3}{8}$ | 5 |
| Dimension | $d$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | $1\frac{3}{4}$ |
| Dimension | $e$ | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $3\frac{1}{4}$ | 4 | $4\frac{5}{8}$ | $5\frac{1}{8}$ | $5\frac{3}{4}$ |
| Half length of valve seat | $f$ | $4\frac{1}{4}$ | 5 | 6 | 7 | 8 | $8\frac{3}{4}$ | $9\frac{3}{4}$ |
| Length of cut-off valve | $g$ | $8\frac{5}{8}$ | $10\frac{3}{8}$ | $12\frac{3}{8}$ | $14\frac{3}{8}$ | $16\frac{3}{8}$ | $18\frac{3}{8}$ | $20\frac{3}{8}$ |
| Turning movement of valve | $h$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{1}{4}$ | $2\frac{5}{8}$ | 3 | $3\frac{3}{8}$ |
| Cut-off at mean position of governor | | ·13 | ·13 | ·13 | ·13 | ·13 | ·13 | ·13 |

All Dimensions are given in Inches.

### Rider's Valve Gear.

Rider's valves differ from Meyer's in having the working edges of the cut-off valve formed as a right and left hand screw, the valve itself being turned partially round in its seat, so as to give the same effect as the separate valves of Meyer moved further apart or nearer

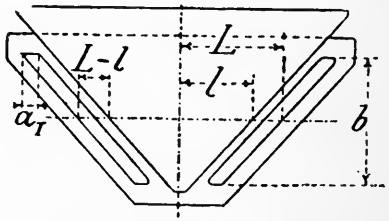



Fig. 620.

together by means of the right and left hand screws and nuts. The effect is the same if the valve is a flat plate with edges inclined right and left, fig. 620; if the plate be moved down the distance L – $l$ is decreased, and if the plate be moved upwards increased.

Fig. 621. Fig. 622.

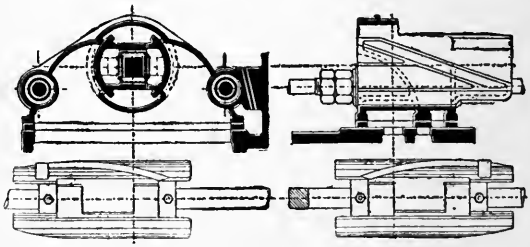
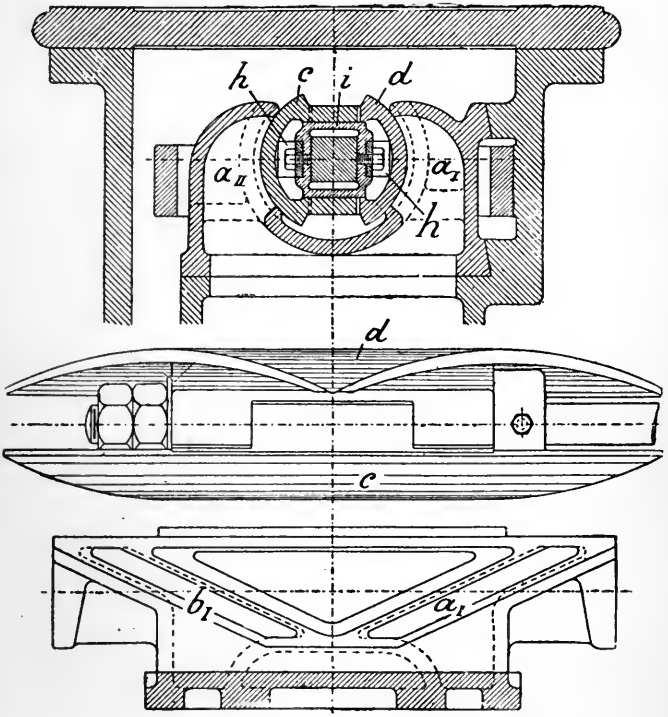


Fig. 623.

A modification of Rider's valve by Leutert of Halle is shown in figs. 621—626. The cut-off valve is in two parts, $c$ and $d$, figs. 624—626, this giving short steam ports, and also rendering the necessary adjustment for variation of expansion of less range. On the back of the main valve are four ports, $a_1$, $a_{11}$, $b_1$, $b_{11}$; the first two unite into one port at the right hand end of the valve, and the two latter into one port at the left hand end of the valve; the cut-off valve has a square

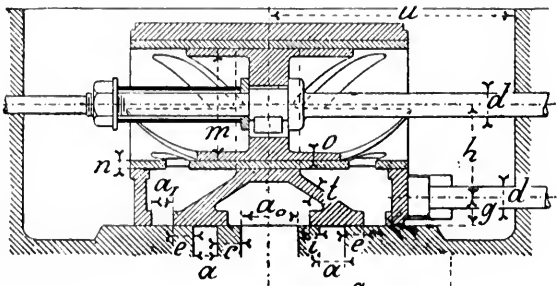
spindle by which it is turned in its seat to vary the cut-off. The two parts of the cut-off valve are kept up to their seat by springs, *h*.




Figs. 624—626.

These valves are usually controlled by the governor. The two halves of the valve form a kind of piston valve, and should work with very little friction.

Fig. 627.



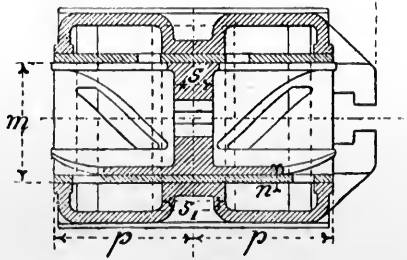
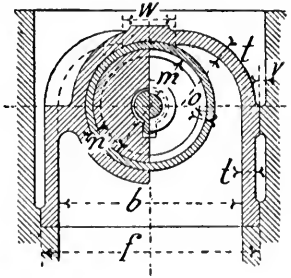




Fig. 628.

Fig. 629.



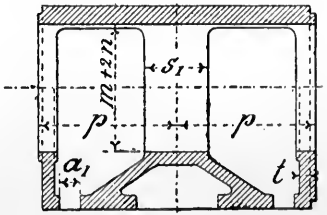




Fig. 630.

TABLE 62.—**Dimensions of Rider's Closed Valves** (Figs. 627—630).

| H | D | $a_0$ | $a$ | $a_1$ | $b$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ | $m$ | $n$ | $o$ | $p$ | $q$ | $s$ | $s_1$ | $t$ | $u$ | $v$ | $w$ | $r=r_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 10 | $1\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $5\frac{5}{8}$ | $\frac{11}{16}$ | $1\frac{1}{8}$ | $\frac{1}{2}$ | $6\frac{3}{4}$ | $1\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $4\frac{1}{4}$ | $5\frac{13}{16}$ | $1\frac{3}{8}$ | $2\frac{3}{8}$ | $\frac{1}{2}$ | $7\frac{1}{4}$ | $\frac{1}{4}$ | $1\frac{1}{2}$ | 1 |
| 24 | 12 | $1\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $6\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $8\frac{3}{8}$ | $1\frac{3}{8}$ | $3\frac{5}{8}$ | $\frac{5}{16}$ | 4 | $\frac{3}{8}$ | $\frac{3}{8}$ | 5 | $6\frac{3}{4}$ | $1\frac{5}{8}$ | $2\frac{5}{8}$ | $\frac{1}{2}$ | $8\frac{5}{8}$ | $\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{5}{16}$ |
| 28 | 14 | $2\frac{3}{8}$ | 1 | $\frac{7}{8}$ | $8\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ | $\frac{3}{4}$ | 10 | $1\frac{5}{8}$ | $4\frac{3}{8}$ | $\frac{5}{16}$ | $4\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 6 | $7\frac{7}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{9}{16}$ | $10\frac{1}{4}$ | $\frac{3}{8}$ | 2 | $1\frac{5}{8}$ |
| 32 | 16 | $2\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | 10 | 1 | $1\frac{3}{8}$ | $\frac{7}{8}$ | $11\frac{5}{8}$ | $1\frac{3}{4}$ | 5 | $\frac{3}{8}$ | $5\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 7 | $9\frac{1}{8}$ | $1\frac{7}{8}$ | 3 | $\frac{9}{16}$ | $11\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{4}$ | $1\frac{7}{8}$ |
| 36 | 18 | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $11\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | 1 | $13\frac{3}{8}$ | $1\frac{3}{4}$ | $5\frac{3}{4}$ | $\frac{1}{2}$ | $6\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{1}{2}$ | 8 | $10\frac{1}{4}$ | 2 | $3\frac{1}{4}$ | $\frac{5}{8}$ | $13\frac{1}{4}$ | $\frac{3}{8}$ | $2\frac{3}{8}$ | $2\frac{1}{8}$ |
| 40 | 20 | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $13\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{8}$ | $15\frac{1}{4}$ | 2 | $6\frac{3}{8}$ | $\frac{1}{2}$ | $7\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $8\frac{3}{4}$ | $11\frac{1}{4}$ | $2\frac{1}{8}$ | $3\frac{3}{8}$ | $\frac{11}{16}$ | $14\frac{3}{8}$ | $\frac{3}{8}$ | $2\frac{5}{8}$ | $2\frac{1}{2}$ |
| 44 | 22 | 4 | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $14\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $1\frac{1}{4}$ | $16\frac{3}{4}$ | $2\frac{1}{4}$ | $7\frac{1}{4}$ | $\frac{5}{8}$ | $8\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $9\frac{3}{4}$ | $12\frac{1}{2}$ | $2\frac{1}{4}$ | $3\frac{5}{8}$ | $\frac{3}{4}$ | 16 | $\frac{3}{8}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ |

All Dimensions are given in Inches.

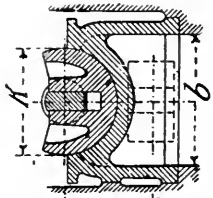



Fig. 633.

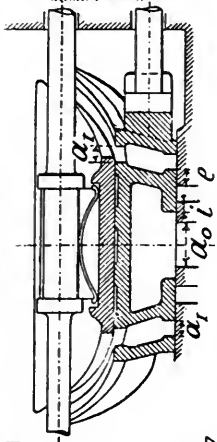



Fig. 632.

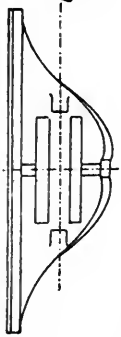


Fig 631.

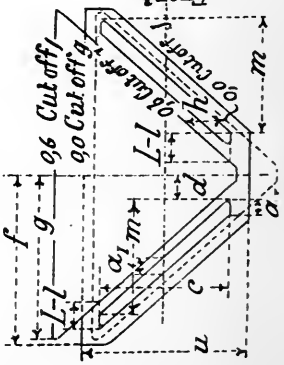



Fig. 634.

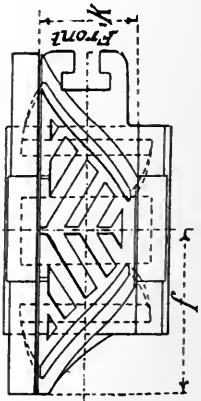



Fig. 635.

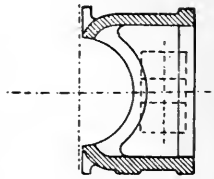


Fig. 636.

TABLE 63.—**Dimensions of Rider's Open Valves** (Figs. 631—636).

| | | | | | | |
|---|---|---|---|---|---|---|
| Stroke | H | 16 | 20 | 24 | 28 | 32 |
| Diameter of piston | D | 8 | 10 | 12 | 14 | 16 |
| Diameter of cut-off valve | $k$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $4\frac{5}{8}$ | $5\frac{5}{8}$ | $6\frac{5}{8}$ |
| Half circumference | $u$ | $8\frac{5}{8}$ | $11\frac{5}{16}$ | $14\frac{1}{2}$ | $17\frac{5}{8}$ | $20\frac{3}{4}$ |
| Width of port | $a_1$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{11}{16}$ | $\frac{7}{8}$ | 1 |
| $L-l$ for ·0 cut-off | | $-\frac{3}{8}$ | $-\frac{7}{16}$ | $-\frac{1}{2}$ | $-\frac{11}{16}$ | $-\frac{3}{4}$ |
| $L-l$ for ·6 cut-off | | $\frac{11}{16}$ | $\frac{7}{8}$ | $1\frac{3}{16}$ | $1\frac{5}{16}$ | $1\frac{13}{16}$ |
| Height of port $c$ = about ·8 of $b$ | $c$ | $3\frac{5}{8}$ | $4\frac{3}{8}$ | $5\frac{5}{8}$ | $6\frac{3}{4}$ | $8\frac{3}{8}$ |
| Dimension | $d$ | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ | $1\frac{1}{2}$ | 2 |
| Dimension | $m$ | $3\frac{1}{8}$ | 4 | 5 | $6\frac{1}{8}$ | $7\frac{1}{2}$ |
| Half length of main valve | $f$ | $4\frac{3}{4}$ | 6 | $7\frac{3}{8}$ | $9\frac{3}{8}$ | $11\frac{3}{8}$ |
| Half length of cut-off valve | $g$ | $4\frac{5}{8}$ | $5\frac{3}{4}$ | 7 | 9 | 11 |
| Turning movement of cut-off valve | $h$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{7}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ |
| Cut-off with governor in mean position | | ·13 | ·13 | ·13 | ·13 | ·13 |

All Dimensions are given in Inches

## Connection between Rider's Valve Gear and the Governor.

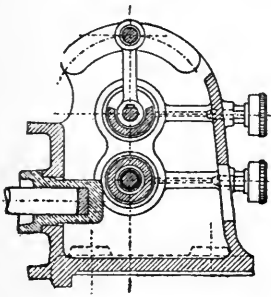


Fig. 637.

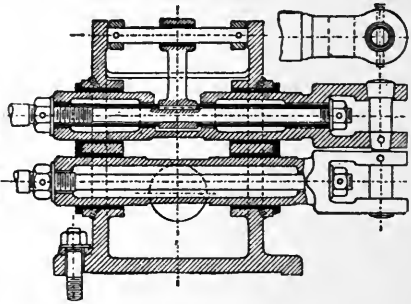


Fig. 638.

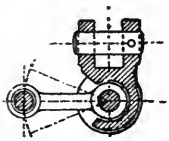


Fig. 639.

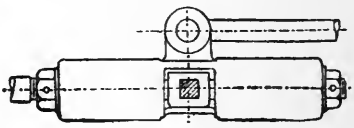


Fig 640.

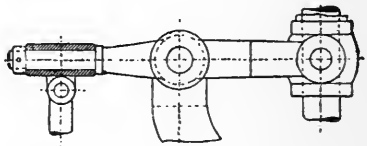


Fig. 641.

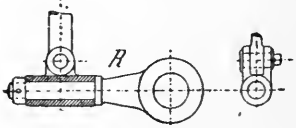



Fig. 642.

The connection between Rider's valve gear and the governor is shown in various ways in figs. 637—642. Figs. 637, 638, show a method by Starke and Hoffman, with cast-iron guides to the valve rods; figs. 639, 640, a method by Leutert; figs. 641, 642, a method of connection with a kind of universal joint, to allow for the backwards and forwards movement of the valve rod.

**Connection between Rider's Valve Gear and Governor.**

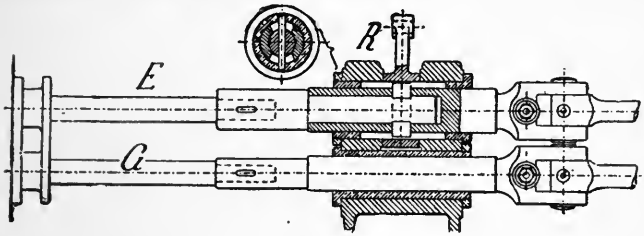



Fig. 643.

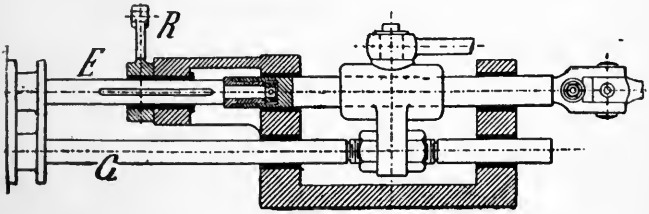



Fig. 644.

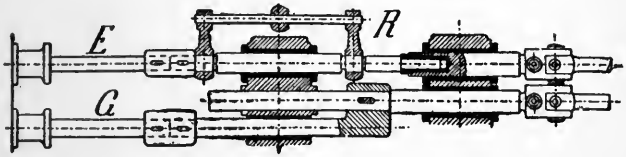



Fig. 645.

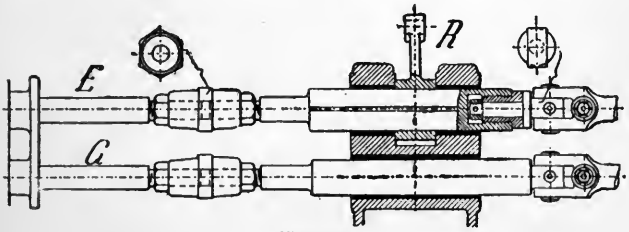



Fig. 646.

G, the main valve rod: E, the cut-off valve rod; R, the arm to which the governor rod is attached.

**Connection between Rider's Valve Gear and Governor.**

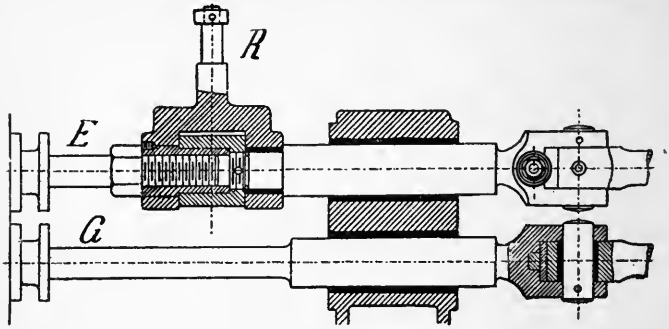



Fig. 647.

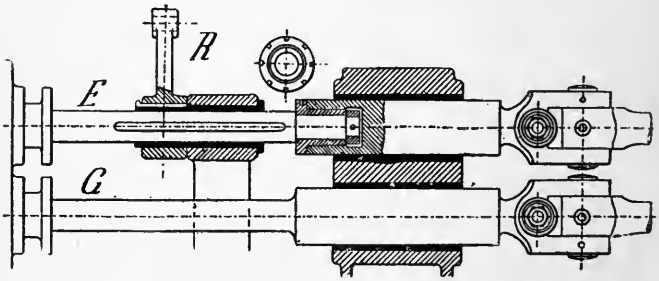
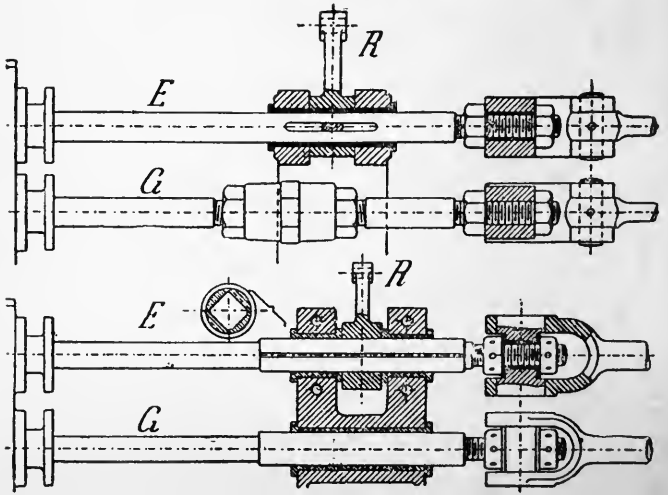



Fig. 648.



**Remarks on the Governor Bracket** (Figs. 651—663).

The combined governor bracket and valve rod guide on the next page may be taken as an example, a somewhat complicated piece of designing, but at the same time a substantial fixing for the governor, driving gear and guides. In engine design, especially with horizontal girder engines, it is well to have as few fixings on the girder as possible, for neatness and other obvious reasons. The whole of the governor gear and attachment to the valve rod, in this case, can be fitted up together, ready to bolt on the engine girder. In cases where a feed-pump is fitted to the engine, the barrel can often be made in the same casting as the valve-rod guides with the necessary valve boxes bolted on. This forms a very compact arrangement, and if, as may happen, the pump centre comes far out from the girder, a stay of wrought iron can be fitted from the pump casting to the slide valve chest to take the thrust of the pump.

By making the flanges at both ends of the pump barrel of the same size, the pump can be used for both right- and left-hand engines, a very important point in the economical manufacture of steam engines, and in many other machines.

In figs. 651—663 one of the valve-rod guides is shown bushed with brass or bronze. If both guide-plunger and guide are of cast iron, there is certainly no necessity for this, although it is often convenient for the owner of an engine to have such guides bushed, even if it is only with cast iron, in order that new bushes can be supplied by the maker, without having to supply a new bracket, with a risk of variation in the centres, causing trouble and delay.

**Combined Bracket for carrying Governor and Valve-Rod Guides** (Figs. 651—663).

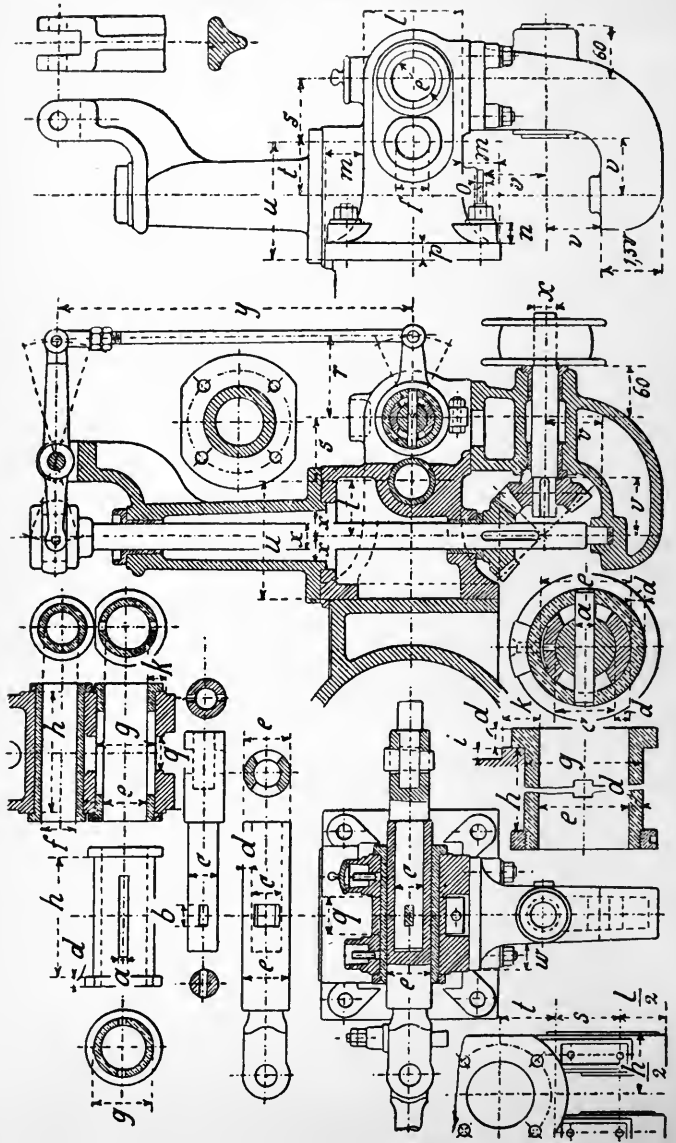


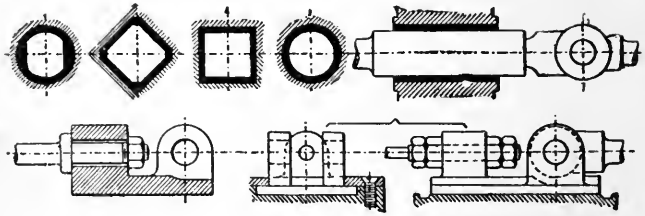
TABLE 64.—**Dimensions of Valve-Rod Guides and Governor Stands for Rider's Valve Gear** (Figs. 651—663).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* | *x* | *y* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 10 | ½ | 1 | 1⅜ | ⅜ | 2¼ | 1⅝ | 3 | 6½ | ¼ | 1 | 5 | 2 | ⅞ | ⅝ | ¾ | 1¾ | 4 | 3¼ | 2¾ | 5⅝ | 3 | 1¼ | 1⅜ | 16 |
| 24 | 12 | ½ | 1 | 1½ | 7/16 | 2⅜ | 1¾ | 3⅜ | 7 | ¼ | 1⅛ | 5¼ | 2½ | 1 | ¾ | ⅞ | 2 | 4¼ | 3⅝ | 3 | 6⅜ | 3¼ | 1⅜ | 1⅜ | 18 |
| 28 | 14 | 9/16 | 1⅛ | 1⅝ | ½ | 2⅝ | 2 | 3⅝ | 7¾ | ¼ | 1¼ | 6 | 2¾ | 1 | ¾ | 1 | 2⅛ | 4½ | 4⅜ | 3⅛ | 7¼ | 3⅜ | 1½ | 1½ | 20 |
| 32 | 16 | ⅝ | 1¼ | 1⅞ | ½ | 2⅞ | 2⅛ | 4 | 8¼ | ¼ | 1¼ | 6½ | 3¼ | 1¼ | ⅞ | 1 | 2⅜ | 4⅝ | 5 | 3¼ | 8 | 3½ | 1⅝ | 1½ | 22 |
| 36 | 18 | ⅝ | 1¼ | 2 | 9/16 | 3⅛ | 2⅜ | 4¼ | 9¼ | ⅜ | 1⅜ | 7 | 3¾ | 1⅜ | 1 | 1⅛ | 2½ | 4¾ | 5¾ | 3⅜ | 9 | 3¾ | 1¾ | 1½ | 24 |
| 40 | 20 | ¾ | 1⅜ | 2¼ | ⅝ | 3⅜ | 2½ | 4⅝ | 9¾ | ⅜ | 1⅜ | 7¾ | 4 | 1⅜ | 1 | 1¼ | 2⅝ | 5¼ | 6⅜ | 3⅝ | 9 | 3⅞ | 2 | 1¾ | 26 |
| 44 | 22 | ¾ | 1½ | 2⅜ | ⅝ | 3⅝ | 2¾ | 4⅞ | 10 | ⅜ | 1½ | 8 | 4¼ | 1½ | 1¼ | 1¼ | 2¾ | 5¾ | 7¼ | 3¾ | 10 | 4 | 2⅜ | 1¾ | 28 |

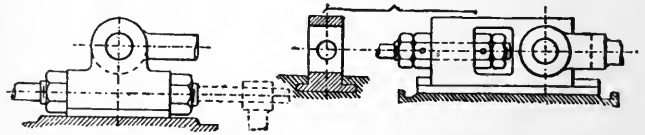
All Dimensions are given in Inches.

## Valve Rod Guides and Joints

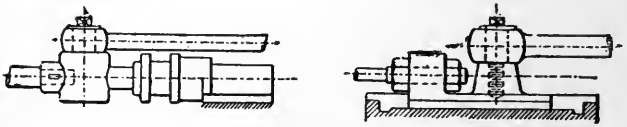
Figs. 664—668.



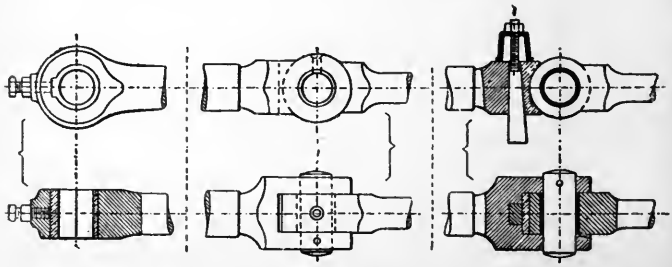
Figs. 669—671.



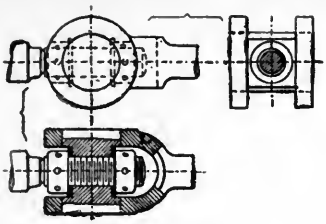
Figs. 672—675.



Figs. 676, 677.



Figs. 678—681.



Figs. 682—684.

Figs. 664 to 685 show a variety of examples of valve-rod joints and guides. That shown in fig. 685, is a very useful form when the

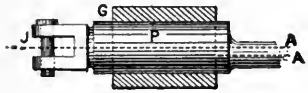



Fig. 685.

eccentric rod and valve rod are not in line, the guide plunger, P, valve rod and joint, J, being in one forging, and turned in the lathe on two centres, A, A ; this form is used in locomotives.

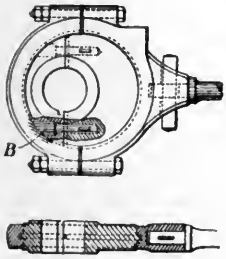



Fig. 685*a*.

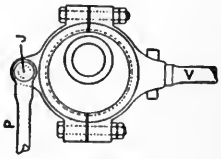
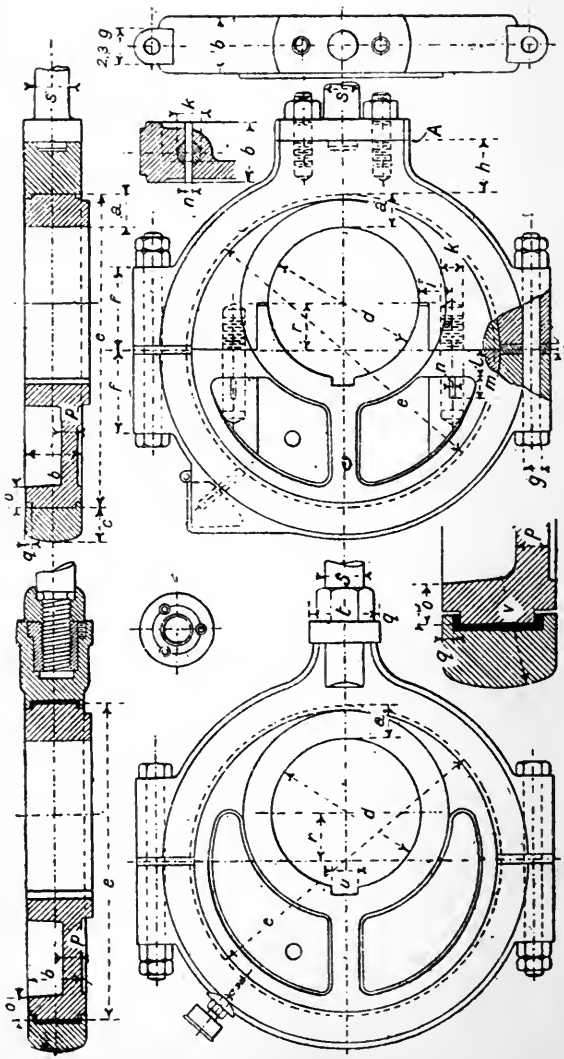



Fig. 685*b*.

Fig. 585*a* shows an eccentric in halves joined by cottered bolts ; the head of the bolt *B* is turned with eccentric sheave when the two halves are bolted together. This method saves room, and is suitable for many small eccentrics where there is no space for bolts, as in fig. 693. Fig. 685*b* shows an arrangement for working two rods off one strap, V and *a*. This is sometimes useful in small vertical engines, where the feed pump and slide valve have to be worked off one eccentric, the pump rod being jointed, as shown, to the outer end of the strap.

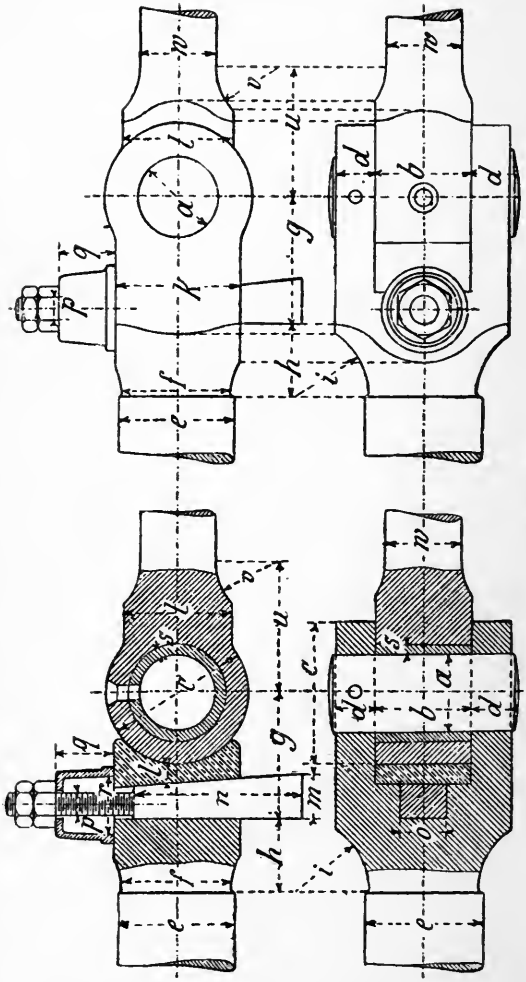


Figs. 681—693.

TABLE 65.—**Dimensions of Eccentrics** (Figs. 686—693).

| H | D | *r* | *d* | *a* | *b* | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *s* | *t* | *u* | *v* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 6 | — | — | — | $1\frac{1}{2}$ | $\frac{7}{8}$ | — | 2 | $\frac{1}{2}$ | $1\frac{1}{2}$ | — | — | — | — | — | $\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{1}{4}$ | 1 | $2\frac{5}{8}$ | $\frac{1}{2}$ | $1\frac{1}{2}$ |
| 16 | 8 | — | — | — | $1\frac{3}{4}$ | 1 | — | $2\frac{3}{8}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ | — | — | — | — | — | $\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{1}{4}$ | $1\frac{1}{4}$ | $2\frac{3}{4}$ | $\frac{5}{8}$ | 2 |
| 20 | 10 | 1 | $5\frac{1}{4}$ | $\frac{7}{8}$ | 2 | 1 | 9 | $2\frac{3}{4}$ | $\frac{5}{8}$ | 2 | 1 | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | 1 | $\frac{5}{8}$ | $\frac{1}{4}$ | $1\frac{3}{8}$ | 3 | $\frac{5}{8}$ | $2\frac{1}{2}$ |
| 24 | 12 | $1\frac{5}{16}$ | 6 | $1\frac{1}{8}$ | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $10\frac{7}{8}$ | $3\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{4}$ | 1 | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{5}{16}$ | $1\frac{1}{2}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ | $2\frac{1}{2}$ |
| 28 | 14 | $1\frac{5}{8}$ | $7\frac{3}{8}$ | $1\frac{1}{4}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | $13\frac{1}{8}$ | $3\frac{5}{8}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{8}$ | 1 | $\frac{3}{4}$ | $\frac{5}{16}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{5}{16}$ | $1\frac{5}{8}$ | $3\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{3}{4}$ |
| 32 | 16 | $1\frac{7}{8}$ | 8 | $1\frac{3}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{4}$ | $14\frac{1}{2}$ | 4 | $\frac{7}{8}$ | $2\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | 1 | $\frac{7}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{5}{16}$ | $1\frac{3}{4}$ | $3\frac{5}{8}$ | $\frac{3}{4}$ | 3 |
| 36 | 18 | $2\frac{1}{8}$ | $8\frac{5}{8}$ | $1\frac{3}{8}$ | 3 | $1\frac{3}{8}$ | $15\frac{5}{8}$ | $4\frac{5}{8}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{3}{8}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{5}{16}$ | 2 | 4 | $\frac{3}{4}$ | $3\frac{1}{4}$ |
| 40 | 20 | $2\frac{1}{2}$ | 10 | $1\frac{1}{2}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | 18 | $4\frac{3}{4}$ | 1 | 3 | 2 | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{7}{8}$ | $\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{8}$ | $2\frac{1}{8}$ | $4\frac{1}{2}$ | $\frac{3}{4}$ | $3\frac{1}{2}$ |
| 44 | 22 | $2\frac{3}{4}$ | $11\frac{1}{4}$ | $1\frac{5}{8}$ | $3\frac{1}{2}$ | $1\frac{1}{2}$ | 20 | $5\frac{1}{4}$ | 1 | $3\frac{1}{4}$ | $2\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | 1 | $\frac{3}{8}$ | $1\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{3}{8}$ | $2\frac{1}{4}$ | $4\frac{1}{2}$ | $\frac{7}{8}$ | $3\frac{1}{2}$ |

All Dimensions are given in Inches.

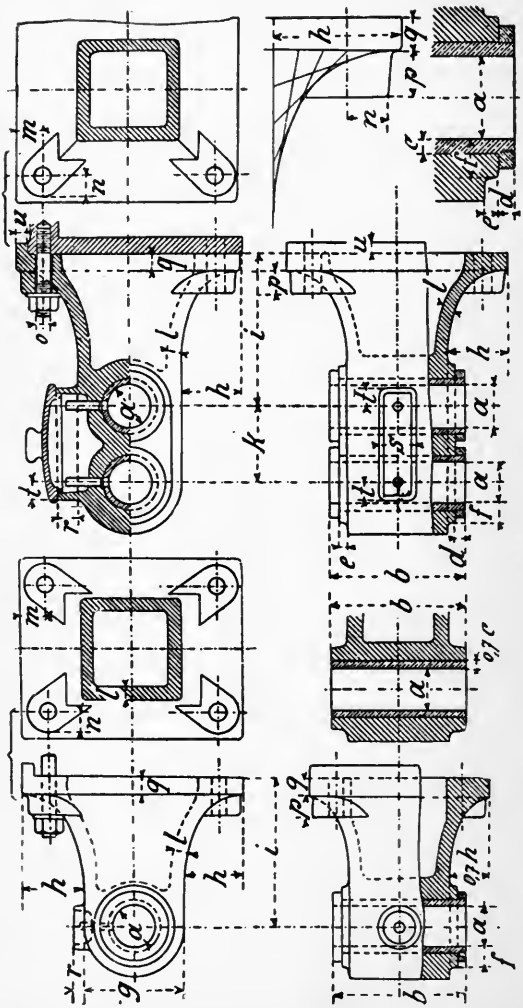


Figs. 694—697.

TABLE 66.—**Dimensions of Valve and Eccentric Rod Joints** (Figs. 694—697).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 6 | $\frac{7}{8}$ | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $1\frac{1}{8}$ | 1 | $1\frac{5}{8}$ | $\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{3}{8}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{3}{4}$ |
| 16 | 8 | 1 | $1\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | 2 | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{3}{4}$ | $\frac{1}{4}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{8}$ | 1 | 1 | $\frac{3}{16}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{7}{8}$ |
| 20 | 10 | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $2\frac{3}{8}$ | $\frac{5}{8}$ | $1\frac{5}{8}$ | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | 2 | $\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | 1 | 1 | $\frac{3}{16}$ | $1\frac{1}{2}$ | 2 | $\frac{7}{8}$ | 1 |
| 24 | 12 | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $2\frac{5}{8}$ | $\frac{5}{8}$ | $1\frac{7}{8}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $2\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{1}{8}$ | 1 | $\frac{3}{16}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | 1 | $1\frac{1}{8}$ |
| 28 | 14 | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $\frac{3}{4}$ | 2 | $1\frac{7}{8}$ | $2\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{3}{8}$ | $2\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{7}{8}$ | 3 | $\frac{7}{8}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{3}{16}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ | 1 | $1\frac{3}{8}$ |
| 32 | 16 | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{3}{4}$ | $\frac{3}{4}$ | $2\frac{1}{8}$ | 2 | $2\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{3}{8}$ | $2\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{7}{8}$ | $3\frac{1}{8}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $\frac{1}{4}$ | 2 | $2\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ |
| 36 | 18 | $1\frac{1}{2}$ | 2 | 3 | $\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $\frac{3}{8}$ | $\frac{7}{8}$ | $3\frac{1}{4}$ | 1 | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{1}{4}$ | $2\frac{1}{8}$ | $2\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ |
| 40 | 20 | $1\frac{1}{2}$ | $2\frac{1}{8}$ | $3\frac{1}{8}$ | $\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $2\frac{3}{4}$ | $\frac{3}{8}$ | $\frac{7}{8}$ | $3\frac{3}{8}$ | 1 | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ |
| ~~44~~ | 22 | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $3\frac{1}{4}$ | $\frac{7}{8}$ | $2\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $1\frac{5}{8}$ | $1\frac{5}{8}$ | $2\frac{7}{8}$ | $\frac{3}{8}$ | 1 | $3\frac{5}{8}$ | 1 | $\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{1}{4}$ | $2\frac{3}{8}$ | 3 | $1\frac{3}{8}$ | 2 |

All Dimensions are given in Inches.



Figs. 698—705.

TABLE 67.—**Dimensions of Valve-Rod Guides for Simple and Meyer's Valve Gears** (Figs. 698—705).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 6 | 1½ | 2¾ | ¼ | 5/16 | ¼ | ⅝ | 3⅝ | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 16 | 8 | 1½ | 3½ | ¼ | 5/16 | ¼ | ⅝ | 3¾ | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 20 | 10 | 1⅝ | 4½ | 5/16 | ⅜ | ¼ | ¾ | 4¼ | 2 | 4¾ | 3¼ | ½ | 1¼ | 1 | ⅝ | ¾ | ¾ | ¾ | 1¼ | ¾ | ⅜ |
| 24 | 12 | 1¾ | 5¼ | 5/16 | ⅜ | ¼ | ⅞ | 4⅝ | 2⅜ | 5¾ | 3⅜ | 9/16 | 1¼ | 1 | ⅝ | ⅞ | ¾ | ¾ | 1¼ | ¾ | ⅜ |
| 28 | 14 | 2 | 6 | ⅜ | ½ | ⅜ | 1 | 5 | 2¾ | 6¾ | 3⅝ | 9/16 | 1⅜ | 1 | ¾ | 1 | ⅞ | 1 | 1½ | ¾ | ½ |
| 32 | 16 | 2⅛ | 6¾ | ⅜ | ½ | ⅜ | 1 | 5¼ | 3¼ | 8 | 3⅞ | ⅝ | 1½ | 1 | ¾ | 1 | 1 | 1 | 2 | ⅞ | ½ |
| 36 | 18 | 2⅜ | 7¾ | ⅜ | ½ | ⅜ | 1⅛ | 5⅝ | 3⅝ | 9 | 4¼ | 11/16 | 1½ | 1¼ | ⅞ | 1⅛ | 1 | 1¼ | 2½ | ⅞ | ⅝ |
| 40 | 20 | 2½ | 8½ | ⅜ | ½ | ⅜ | 1¼ | 6 | 4 | 10 | 4⅜ | ¾ | 1⅝ | 1¼ | ⅞ | 1¼ | 1⅛ | 1⅜ | 2¾ | 1 | ⅝ |
| 44 | 22 | 2¾ | 8¾ | ⅜ | ½ | ⅜ | 1¼ | 6⅜ | 4¼ | 10½ | 4⅝ | ¾ | 1¾ | 1¼ | 1 | 1¼ | 1¼ | 1⅜ | 3 | 1 | ¾ |

All Dimensions are given in Inches.

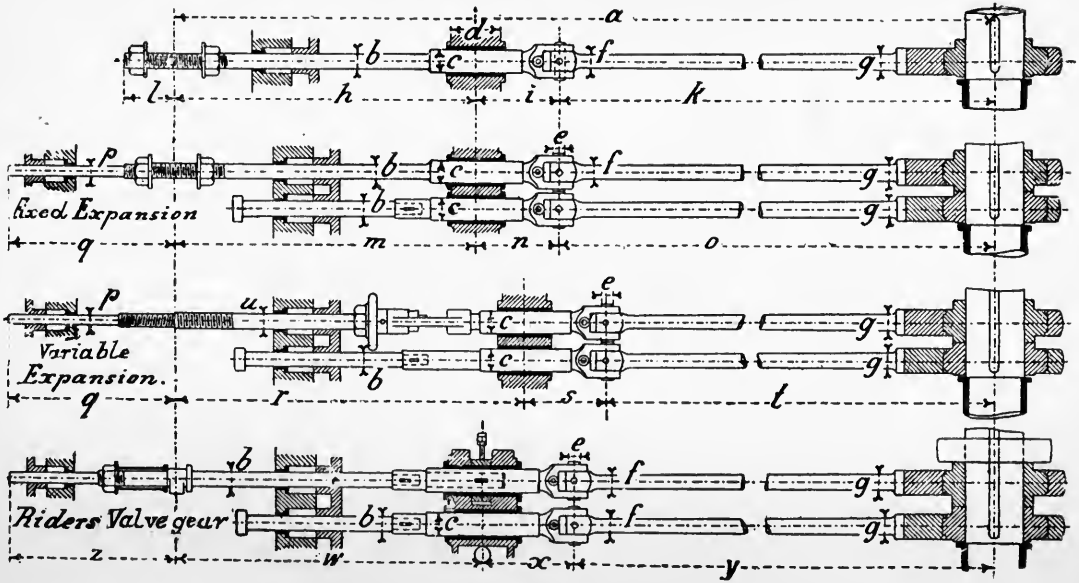


Fig 706
Fig. 707.
fixed Expansion
Fig. 708.
Variable
Expansion.
Fig. 709.
Riders Valve gear
a
b
c
d
e
f
g
h
i
k
l
m
n
o
p
q
r
s
t
u
w
x
y
z

Figs. 706—709.

TABLE 68.—**Dimensions of Eccentric Rods and Valve Rods** (Figs. 706—709).

| | | Dimensions common to figs. 706—709. | | | | | | | Dimen. for fig. 706. | | | | Dimensions for fig. 707. | | | | | Dimensions for fig. 708, for Meyer's valve gear adjusted by hand | | | | | Dimensions for fig. 709, for Rider's valve gear adjusted by governor. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | Threads per in. | *w* | *x* | *y* | *z* |
| 12 | 6 | 58 | $\frac{7}{8}$ | $1\frac{1}{2}$ | $2\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | 1 | 30 | 5 | 23 | $2\frac{5}{8}$ | — | – | – | – | – | – | – | – | – | – | – | .. | – |
| 16 | 8 | $74\frac{3}{8}$ | 1 | $1\frac{1}{2}$ | $3\frac{1}{2}$ | 1 | $\frac{7}{8}$ | $1\frac{1}{4}$ | $33\frac{3}{4}$ | $5\frac{7}{8}$ | 35 | 3 | 35 | $5\frac{7}{8}$ | 33 | $\frac{3}{4}$ | $13\frac{1}{4}$ | $41\frac{3}{4}$ | $5\frac{7}{8}$ | 27 | $1\frac{1}{4}$ | 4 | – | – | – | – |
| 20 | 10 | 90 | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $4\frac{1}{2}$ | $1\frac{1}{8}$ | 1 | $1\frac{3}{8}$ | 35 | 7 | 48 | $3\frac{5}{8}$ | $37\frac{3}{8}$ | $6\frac{5}{8}$ | 46 | $\frac{3}{4}$ | 15 | $43\frac{3}{8}$ | $6\frac{5}{8}$ | 40 | $1\frac{3}{8}$ | 4 | 38 | 8 | 44 | $14\frac{3}{8}$ |
| 24 | 12 | $106\frac{1}{4}$ | $1\frac{3}{16}$ | $1\frac{3}{4}$ | $5\frac{1}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{2}$ | $38\frac{1}{4}$ | 8 | 60 | $4\frac{3}{8}$ | $42\frac{3}{4}$ | $7\frac{1}{2}$ | 56 | $\frac{7}{8}$ | $16\frac{5}{8}$ | $48\frac{3}{4}$ | $7\frac{1}{2}$ | 50 | $1\frac{1}{2}$ | 4 | $42\frac{1}{4}$ | 9 | 55 | 17 |
| 28 | 14 | 122 | $1\frac{1}{4}$ | 2 | 6 | $1\frac{3}{8}$ | $1\frac{3}{8}$ | $1\frac{5}{8}$ | 43 | 9 | 70 | $4\frac{7}{8}$ | 47 | 8 | 67 | 1 | $18\frac{3}{4}$ | 53 | 8 | 61 | $1\frac{5}{8}$ | 4 | $46\frac{1}{4}$ | $9\frac{3}{4}$ | 66 | $19\frac{1}{4}$ |
| 32 | 16 | 138 | $1\frac{3}{8}$ | $2\frac{1}{8}$ | $6\frac{3}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{2}$ | $1\frac{3}{4}$ | – | – | – | – | 49 | 9 | 80 | $1\frac{1}{8}$ | $20\frac{3}{4}$ | 57 | 9 | 72 | $1\frac{3}{4}$ | 4 | $50\frac{1}{2}$ | $10\frac{1}{2}$ | 77 | $21\frac{5}{8}$ |
| 36 | 18 | 154 | $1\frac{3}{8}$ | $2\frac{3}{8}$ | $7\frac{3}{4}$ | $1\frac{1}{2}$ | $1\frac{5}{8}$ | 2 | – | – | – | – | 54 | 10 | 90 | $1\frac{1}{4}$ | $23\frac{1}{4}$ | 63 | 10 | 81 | $1\frac{7}{8}$ | 3 | $56\frac{1}{2}$ | $11\frac{1}{2}$ | 86 | 24 |
| 40 | 20 | $169\frac{3}{4}$ | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $8\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{7}{8}$ | $2\frac{1}{8}$ | – | – | – | – | $59\frac{3}{4}$ | 11 | 100 | $1\frac{3}{8}$ | $24\frac{3}{4}$ | $64\frac{3}{4}$ | 11 | 94 | 2 | 3 | $60\frac{3}{4}$ | 12 | 97 | $25\frac{5}{8}$ |
| 44 | 22 | $186\frac{3}{4}$ | $1\frac{5}{8}$ | $2\frac{3}{4}$ | $8\frac{3}{4}$ | $1\frac{5}{8}$ | 2 | $2\frac{1}{4}$ | – | – | – | – | $61\frac{3}{4}$ | 12 | 113 | $1\frac{3}{8}$ | $26\frac{3}{4}$ | $70\frac{3}{4}$ | 12 | 104 | $2\frac{1}{8}$ | 3 | $64\frac{3}{4}$ | 13 | 109 | 28 |

All Dimensions are given in Inches.

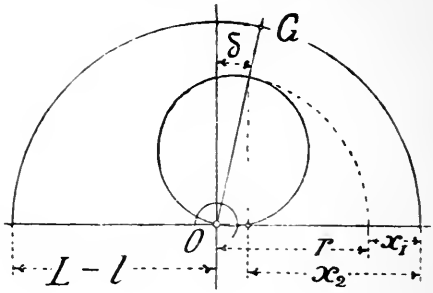



Fig. 710.

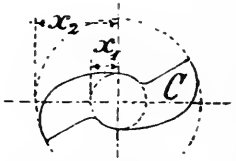



Fig. 711.

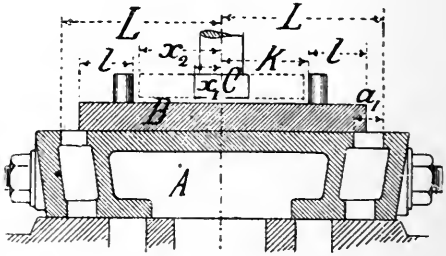



Fig. 712.

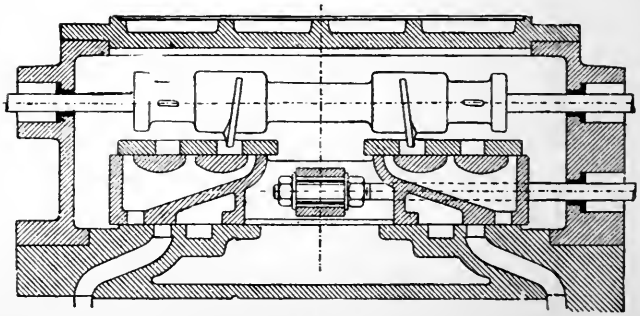


Fig. 713

## Farcot's Valve Gear.

The expansion valve B, fig. 712, is here loose on the back of the main valve A, and is dragged along by friction with the latter; the distance to which the expansion valve is carried is determined by the position of the cam C, figs. 711 and 712; the range of variation in this gear can be from ·0 to ·4. The limit of the latest cut-off is when the crank is at O G, fig. 710, and is dependent on the angle of advance. The valve diagram is constructed as follows:—

$\delta$ = the angle of advance of main valve eccentric; $r$ = the radius of eccentricity of main valve eccentric; $x$ = the smallest diameter of the cam, $\frac{3}{8}''$ to $1''$; $\mathrm{L} - l = r + x_1$; then

$x_2 = \mathrm{L} - l - r \sin. \delta$ = the greatest diameter of the cam.

$2k = 2(\mathrm{L} - l) - a_1$.

$a_1 = < 2(\mathrm{L} - l - x_2)$.

When these equations are satisfied, the port, $a_1$, will be fully open when $x$ is at its least value. The opening of $a_1$ is usually too small, so that two or more ports are required.

Guhrauer's valve gear is shown in fig. 713, and is, in effect, similar to that of Meyer.

### Piston Valves.

Piston valves have been the subject of much ingenuity for many years, and at length are fairly well established in marine and other engines, where steam of very high pressure is used, especially for the high pressure cylinder of triple expansion engines.

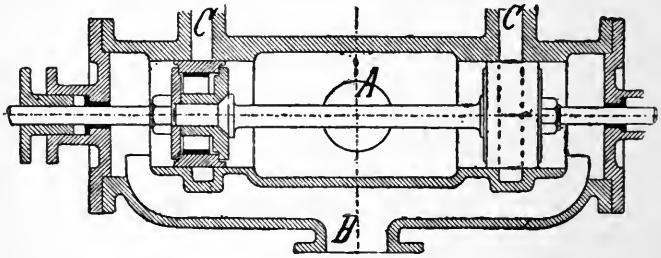



Fig. 714.

An example is shown in fig. 714 for a simple valve gear: C C are the steam ports, one at each end of the cylinder; B, the steam

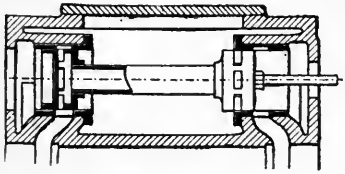


Fig. 715.

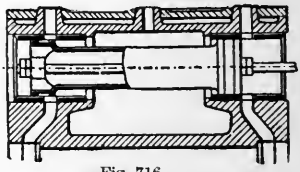


Fig. 716.

supply; A, the exhaust. Other examples are given in figs. 715, 716, and fig. 717 shows an outside view of the cylinder of an engine of 5′ 7″ stroke, with the piston-valve case bolted on by means of flanges.

Figs. 718 — 727 show an example of a piston valve for Rider's valve gear for an engine of 5′ 7″ stroke, 2′ 7″ diameter of piston, and 58 revs. per minute. The variation of cut-off is from ·0 to ·6, and the valve is turned through an angle of 36° by the governor.

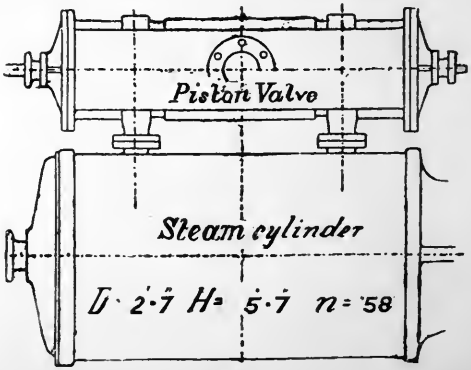
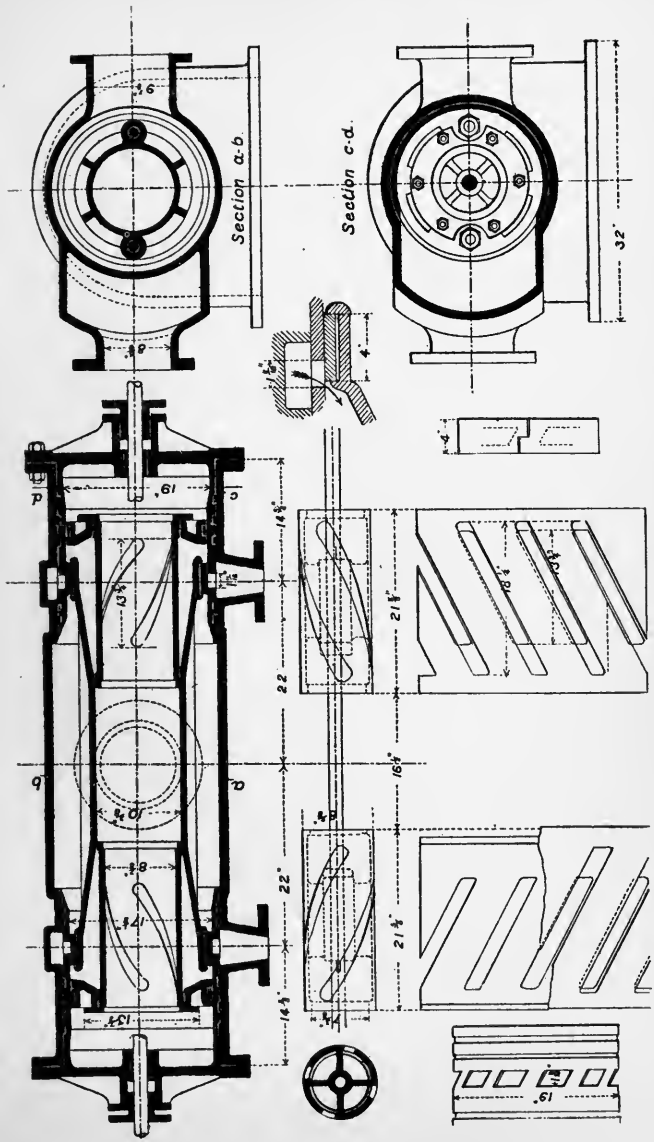



Fig. 717.




Figs. 718—727.

## Reversing Gears.

Reversing gears are chiefly used on locomotives, marine and winding engines, also on traction engines for common roads and steam road-rollers. The prevailing type of reversing gear is the ordinary link motion of Stephenson or some modification of the same, but other types are used for special purposes. Stephenson's link motion

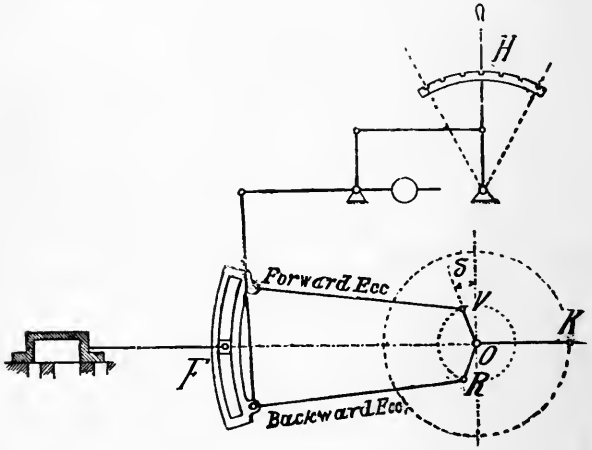



Fig. 728.

is shown in diagram in fig. 728; on the shaft, O, two eccentrics, O V, O R, are keyed; a rod from each of these eccentrics is attached to the ends of the link or sector F, one rod to each end.

A block free to slide in the link F is attached to the end of the valve rod. By means of the hand lever, H, and a system of rods, the

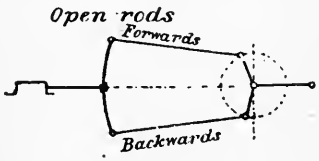



Fig. 729.

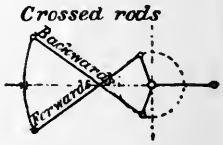



Fig. 730.

link can be raised or lowered, so as to bring either eccentric rod in line with the block; it will be seen that the two eccentrics are set so that one will run the engine backwards, the other forwards. If

the link is in its highest or lowest position, the valve will receive the full stroke of one of the eccentrics ; if the link is in any other position, the stroke of the valve will be reduced, if the link is in a mean position, then the valve will receive the minimum amount of stroke. There are two ways of setting this valve gear, one, with open rods, fig. 729, the other, with crossed rods, fig. 730 ; the angle of advance, $\delta$, is usually made the same for both forward and backward eccentric. The effect of open and crossed rods on the distribution of steam is shown in the valve diagrams, figs. 732, 733.

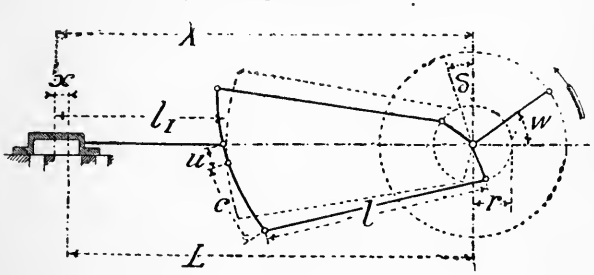



Fig. 731.

In fig. 731,

$r$ = the radius or half stroke of both eccentrics.
$\delta$ = the angle of advance.
$c$ = the half length of the link measured from the centre line to the point where the eccentric rod is attached.
$u$ = the distance from the centre of the block to the centre of the link, $u$ is positive when the link is down and negative when the link is up.
$l$ = the length of the eccentric rod.
$q$ = the radius of the link.
$l_1$ = the length of the valve rod.

for a chosen position of the crank corresponding to an angular movement W, gives for $X_m$ (mean X)—

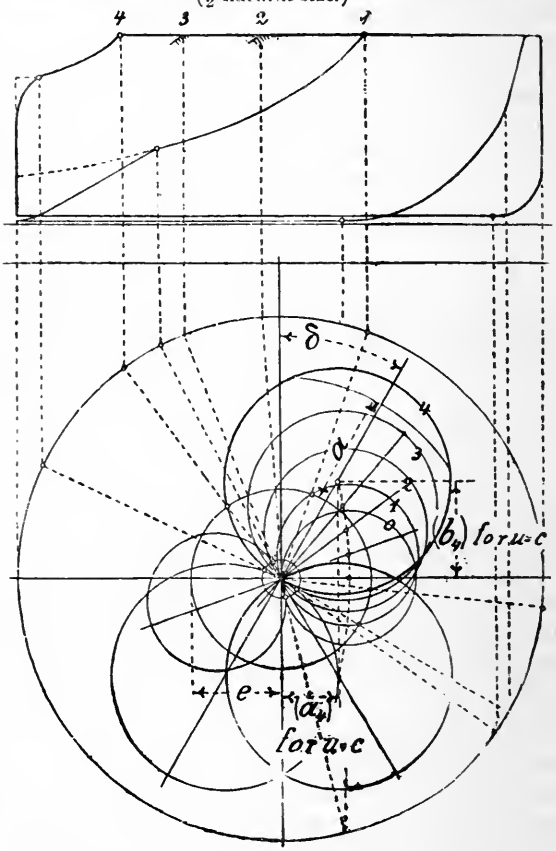
$$X_m = l + l_1 - \frac{r^2}{2\,l} \cos.^2 \delta + (c^2 - u^2)\,\frac{l - q}{2\,l\,q} = L.$$

The link should be curved to a radius equal to the length of the eccentric rod.

**Stephenson's Link Motion with Open Rods.**

($\frac{1}{2}$ natural size.)

Fig. 732




($a = 1{\cdot}18$ ins. ; $r = 2{\cdot}36$ ins. ; $l = 55$ ins. ; $c = 5{\cdot}9$ ins. ; $e = {\cdot}95$ ins. ; $i = {\cdot}27$ ins.)

$$(a) = \tfrac{1}{2}\, r\left(\text{sin. } \delta + \frac{c^2 - u^2}{c\, l} \text{ cos. } \delta\right) \qquad (b) = \tfrac{1}{2}\, r\, \frac{u}{c} \text{ cos. } \delta$$

For $u$ max. $= c$, fig. 731 :—

| Full gear forwards. | Mid gear. | Full gear backwards. |
|---|---|---|
| $(a_1) = \frac{1}{2}\, r$ sin. $\delta$ | $(a_0) = \frac{1}{2}\, r$ sin. $\delta + \frac{1}{2}\, r\, \frac{c}{l}$ cos. $\delta$ | $(a_4) = \frac{1}{2}\, r$ sin. $\delta$ |
| $b_4) = \frac{1}{2}\, r$ cos. $\delta$ | $(b_0) = 0$ | $(b_4) = -\frac{1}{2}\, r$ cos. $\delta$ |

**Stephenson's Link Motion with Crossed Rods.**

($\frac{1}{2}$ natural size.)

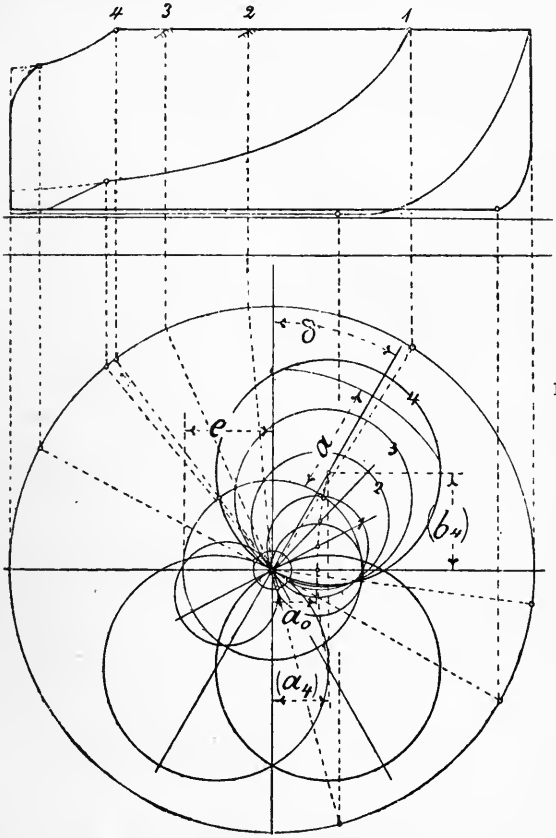



Fig. 733

($a$ = 1·18 ins.; R = 2·36 ins.; $l$ = 55 ins.; $c$ = 5·9 ins.; $e$ = ·95 ins.; $r$ = ·27 ins.)

$$(a) = \tfrac{1}{2} r \left( \text{sin. } \delta - \frac{c^2 - u^2}{c\, l} \cos. \delta \right) \qquad (b) = \tfrac{1}{2} r \frac{u}{c} \cos. \delta$$

For $u$ max. = $c$, fig. 731 :—

| Full gear forwards. | Mid gear. | Full gear backwards. |
|---|---|---|
| $(a_4) = \frac{1}{2} r \sin. \delta$ | $(a_0) = \frac{1}{2} r \sin. \delta - \frac{1}{2} r \frac{c}{l} \cos. \delta$ | $(a_4) = \frac{1}{2} r \sin. \delta$ |
| $(b_4) = \frac{1}{2} r \cos. \delta$ | $(b_0) = 0$ | $(b_4) = -\frac{1}{2} r \cos. \delta$ |

For the distance, $x$, from the centre of the port face to the centre of the valve, fig. 731, we have the following approximate formulæ :—

For open rods,

$$x = r\left(\text{sin. } \delta + \frac{c^2 - u^2}{c\,l} \text{ cos. } \delta\right) \text{cos. } w + \frac{u\,r}{c} \text{ cos. } \delta \text{ sin. } w.$$

For crossed rods,

$$x = r\left(\text{sin. } \delta - \frac{c^2 - u^2}{c\,l} \text{ cos. } \delta\right) \text{cos. } w - \frac{u\,r}{c} \text{ cos. } \delta \text{ sin. } w.$$

These equations may be expressed for Polar co-ordinates :—

For open rods,

$$(a) = \tfrac{1}{2}\, r\left(\text{sin. } \delta + \frac{c^2 - u^2}{c\,l} \text{ cos. } \delta\right);$$

$$(b) = \tfrac{1}{2}\, r\, \frac{u}{c} \text{ cos. } \delta.$$

For crossed rods,

$$(a) = \tfrac{1}{2}\, r\left(\text{sin. } \delta - \frac{c^2 - u^2}{c\,l} \text{ cos. } \delta\right);$$

$$(b) = \tfrac{1}{2}\, r\, \frac{u}{c} \text{ cos. } \delta.$$

Thus we have the equation of a circle which passes through the centre point.

If we now take $u$ max. = C, and have 9 equi-distant notches in the notch plate for the reversing lever, we have the following values of $u$ for the nine different positions :—

| With open rods. | | With crossed rods. |
|---|---|---|
| $u = c$ | Forwards | $u = -c$ |
| $u = \frac{3}{4}\, c$ | | $u = -\frac{3}{4}\, c$ |
| $u = \frac{1}{2}\, c$ | | $u = -\frac{1}{2}\, c$ |
| $u = \frac{1}{4}\, c$ | | $u = -\frac{1}{4}\, c$ |
| $u = 0$ | Mid-gear | $u = 0$ |
| $u = -\frac{1}{4}\, c$ | Backwards | $u = \frac{1}{4}\, c$ |
| $u = -\frac{1}{2}\, c$ | | $u = \frac{1}{2}\, c$ |
| $u = -\frac{3}{4}\, c$ | | $u = \frac{3}{4}\, c$ |
| $u = -c$ | | $u = c$ |

further these values give :—

| With open rods. | With crossed rods. |
|---|---|
| Full gear forwards. | |
| $(a) = \frac{1}{2}\, r$ sin. $\delta$, | $(a) = \frac{1}{2}\, r$ sin. $\delta$, |
| $(b) = \frac{1}{2}\, r$ cos. $\delta$. | $(b) = \frac{1}{2}\, r$ cos. $\delta$. |
| Mid gear. | |
| $(a) = \frac{1}{2}\, r$ sin. $\delta + \frac{1}{2}\, r\, \frac{c}{l}$ cos. $\delta$, | $(a) = \frac{1}{2}\, r$ sin. $\delta - \frac{1}{2}\, r\, \frac{c}{l}$ cos. $\delta$, |
| $(b) = 0$. | $(b) = 0$. |
| Full gear backwards. | |
| $(a) = \frac{1}{2}\, r$ sin. $\delta$, | $(a) = \frac{1}{2}\, r$ sin. $\delta$, |
| $(b) = -\frac{1}{2}\, r$ cos. $\delta$. | $(b) = -\frac{1}{2}\, r$ cos. $\delta$. |

From the diagram fig. 732, it will be seen that the port is only full open to steam when the link is in either extreme position, in any intermediate position the port is only partially opened; on this account it is usual to make the ports very wide.*

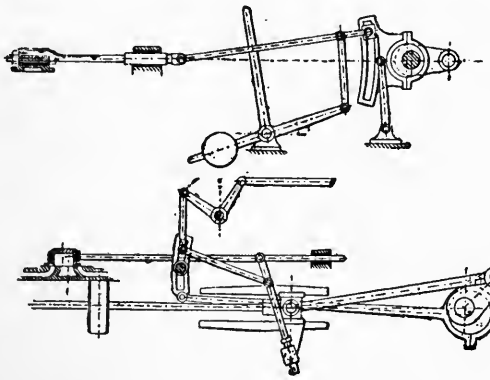


Fig. 734.

Fig. 735.

Fig. 734.—Link motion reversing gear, by Pius Fink, with one eccentric, one link, and one valve.

Fig. 735.—Link motion reversing gear, by Hensinger Von Waldegg, with one eccentric, one link, and one valve.

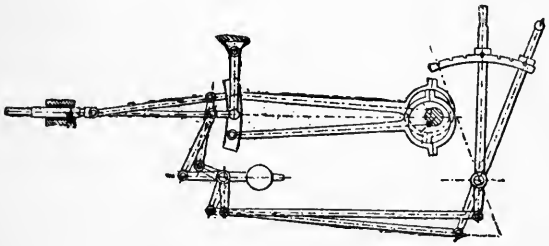


Fig. 736.—Link motion reversing gear by Poloneeau, with two links and two valves.

* A full description and analysis of these link motions will be found in Zeuner's "Treatise on Valve Gears," translated by Moritz Müller. London: Spon.

## Allan's Straight Link Motion.

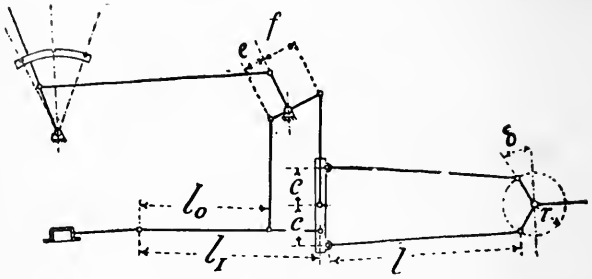



Fig. 737.

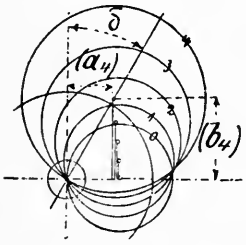



Fig. 738.

With open rods.

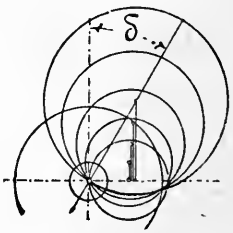



Fig. 739.

With crossed rods.

$$(a) = \tfrac{1}{2}\, r \left( \sin.\, \delta + \frac{nc^2 - u^2}{nc\, l} \cos.\, \delta \right) \qquad (a) = \tfrac{1}{2} r \left( \sin.\, \delta - \frac{nc^2 - u^2}{nc\, l} \cos.\, \delta \right)$$

$$(b) = \frac{r\, u}{2\, c} \left[ \cos.\, \delta - c \frac{(n-1)}{n\, l} \sin.\, \delta \right] \qquad (b) = \frac{r\, u}{2\, c} \left[ \cos.\, \delta + c \frac{(n-1)}{n\, l} \sin.\, \delta \right]$$

thus,
$$n = 1 + \frac{l_1}{l_o} \frac{e}{f}$$

and therefore,
$$\frac{e}{f} = \frac{l_o}{l} \left( 1 + \sqrt{1 + \frac{l}{l_1}} \right).$$

The distinguishing feature of Allan's straight link motion reversing gear, fig. 737, is that the link is a straight bar, not a curved sector, and that link is raised and the block lowered simultaneously by a system of levers, the diagrams, fig. 738, 739, show that the distribution of steam is much the same as with the Stevenson's link motion, but the lead is more nearly constant for all positions of the link.

## Gooch's Link Motion.

This link motion reversing gear, fig. 740, is sometimes called the "fixed link" motion, as the link is suspended from a fixed point, and is not moved up and down, the reversing action being obtained by moving the block up and down in the link.

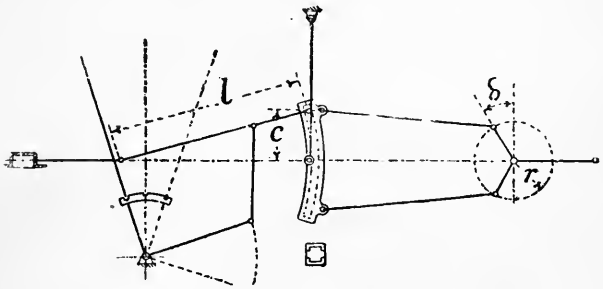



Fig. 740.

Crossed rods give the same distribution of steam, and are seldom used with this motion.

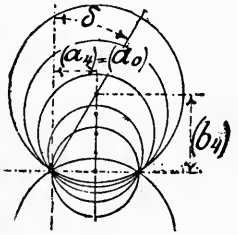



Fig. 741.

With open rods.

$$(a) = \tfrac{1}{2} r \left(\sin.\ \delta + \frac{c}{l} \cos.\ \delta\right),$$

$$(b) = \frac{r}{2} \frac{u}{c} \left(\cos.\ \delta - \frac{c}{l} \sin.\ \delta\right).$$

With crossed rods.

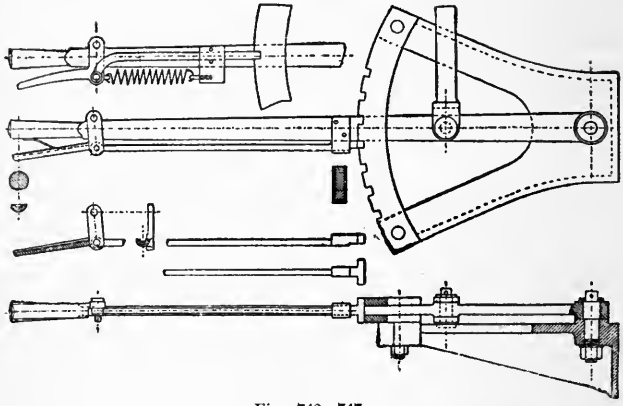
$$(a) = \tfrac{1}{2} r \left(\sin.\ \delta - \frac{c}{l} \cos.\ \delta\right),$$

$$(b) = \frac{r}{2} \frac{u}{c} \left(\cos.\ \delta + \frac{c}{l} \sin.\ \delta\right)$$

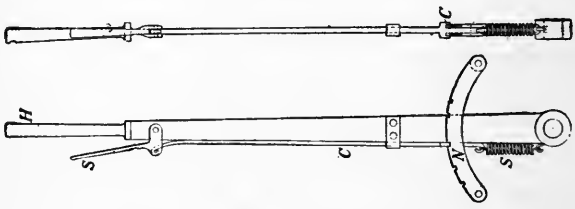
| | |
|---|---|
| $u = +c$ Full gear forwards | $u = -c$, |
| $u = 0$ Mid gear | $u = 0$, |
| $u = -c$ Full gear backwards | $u = +c$. |

In the diagram, fig. 741, for open rods all the centres of the valve circles lie in a straight line, therefore the lead and cut-off are constant.

## Reversing Gears.

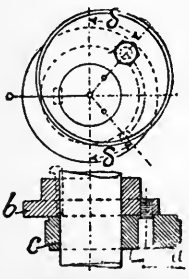


Figs 742–747




Figs 748, 749.

Reversing levers are of various designs : figs. 742 and 749 show two ordinary types, that in fig. 749, has the advantage of having the spring, S, low down out of the way and also the hand lever, H, is carried up well above the handle of the catch, S, so that both hands may be used on the lever.




Figs. 750, 751.

A simple arrangement for reversing the direction of running in small engines, such as agricultural engines, but one that requires the engine to be stopped to effect the reversal, is that of having a disc keyed on the shaft, *b*, fig. 751, and a bolt, *a*, to fix the eccentric to the disc ; a slot in the eccentric allows it to be put over in position for forward or backward running.

One form of reversing gear which has been used on small marine engines consists of a sleeve, *a*, fig. 752, loose on the crank shaft, the eccentric, *b*, is fixed on the sleeve, *a*, and a stud in *c* engages in a thread cut in the shaft, so that when *c* is slid along on the shaft it causes the eccentric to turn round sufficient to reverse the engine.

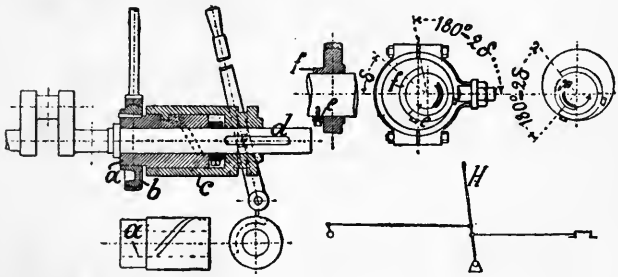



Fig. 752. Fig. 753.

Another form of reversing gear with a loose eccentric, fig. 753, has been largely used in oscillating paddle engines. The eccentric is free to revolve on the shaft between limits formed by a stop, *e*, the eccentric is moved for reversing by means of the lever, H, the valve rod being disengaged from the eccentric rod first by a device known as a "gab" and catch ; it is usual to balance the weight of the eccentric by a plate or disc on the opposite side of the shaft, in order to lessen the labour of reversing.

### Valve Gears with Mushroom and Double-beat Valves.

These valve gears would seem to be elaborations of the original Cornish double-beat valve gears, they are usually rather complicated, and are therefore not very largely used ; the valves of this kind are used in large winding engines, and are capable of being controlled either automatically or by hand. Sections of the valves and seats are given in figs. 754 to 761.

These valves were formerly made of gun metal, but now almost exclusively of cast iron ; the valve seating, also of cast iron, should be especially massive, to avoid the possibility of their getting out of truth. The seatings are frequently cast in one with the cylinder, and require care in the disposition of the metal, in order to secure sound castings. Some examples of the ordinary arrangements of these valves are shown by figs. 762—766 in outline.

## Mushroom and Double-beat Valves.*

Schweiz Locomotive and Engine Works.

Fig. 754.

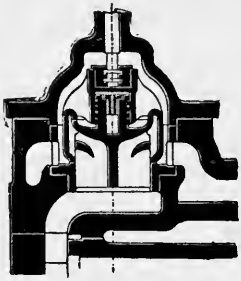
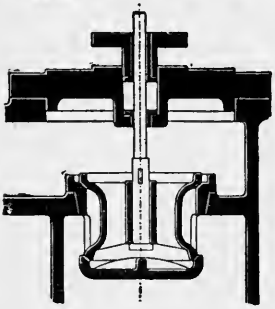


Fig 755



Socin and Wick, Basel.

Fig. 756.

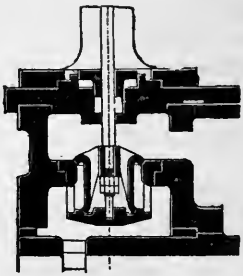
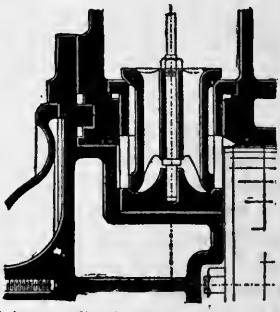


Fig. 757.

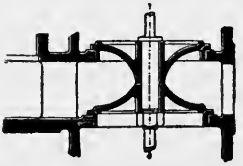


Société Anonyme de Marcinelle et Cowllet, Belgium.

Görlitzer Engine Works.

Fig 758.

Fig. 759.



Pusey, Jones & Co., New York.

Société de l'Home, St. Julien.

C. Nolet, Ghent.

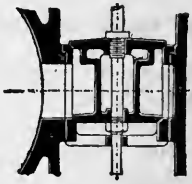
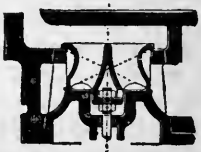


Fig. 760

Fig. 761.



Görlitzer Engine Works.

* These sections are from Uhland's "Corliss Valve Engines."

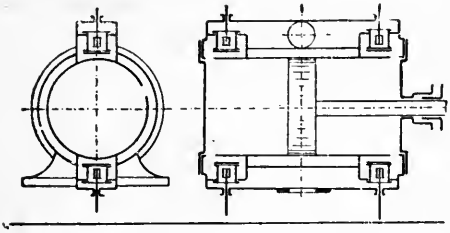


Fig. 762.

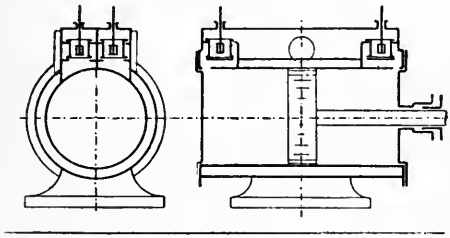


Fig. 763.

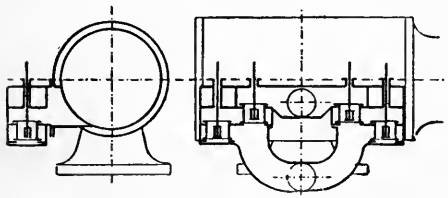


Fig. 764.

Fig. 762.—The two admission valves above, two exhaust valves below. A very common arrangement—for example, Görlitz, Sulzer, &c.

Fig. 763.—The two admission valves and the two exhaust valves on the top of the cylinder.

Fig. 764.—The case for the valves bolted on to the side of the cylinder.

## Valve Gear, with Valves driven by an Eccentric (Figs. 765, 766).

Fig. 765.

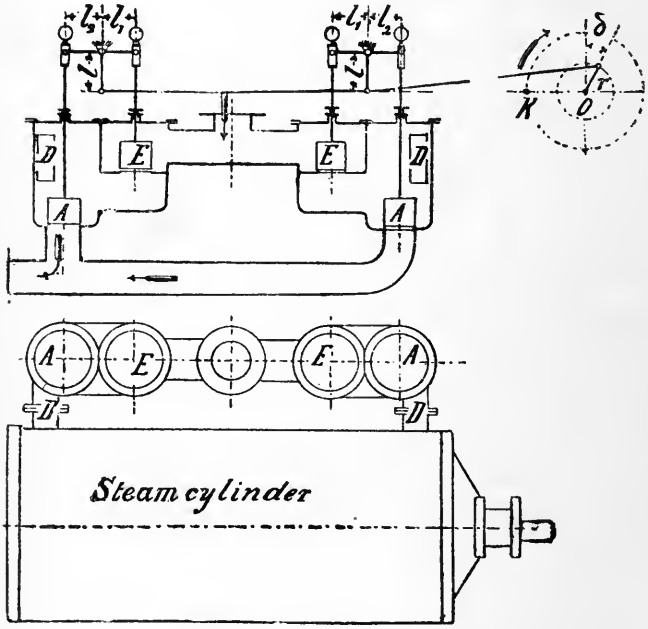



Fig. 766.

The above arrangement (figs. 765, 766) were much used in winding engines—

E E, the steam valves
D D, the steam ports.

The valve motion is obtained by means of an eccentric and bell crank levers. The valve spindles are fitted with weights on their upper ends, to ensure prompt closing. As this valve gear works exactly in the same manner as an ordinary slide valve gear, a link may be in-

troduced, and the whole used as a reversing gear or for a variable cut-off.

In fig. 765,

$h$ = the stroke of the valves.
$v$ = the lead.
$s$ = the amount of play between the end of the lever and the slot in the valve spindle when the eccentric is in the mean position.
$d_1$ = the diameter of the admission valve.
$h_1$ = stroke of admission valve.
$l_1$ = length of lever for admission valve.
$l$ = length of lever, see fig. 765.
$d_2$ = diameter of the exhaust valve.
$h_2$ = stroke of exhaust valve.
$l_2$ = length of lever for exhaust valve.

then we have—

$$\frac{l_2}{l_1} = \frac{h_2}{h_1}\,;\; r = \frac{l}{l_1}(h+s)\,;\; r\sin.\,\delta = \frac{l}{l_1}(s+v)\,;\; \sin.\,\delta = \frac{l}{l_1}\frac{(s+v)}{r}$$

## Valve Gear with Cam Motion.

Fig 767.

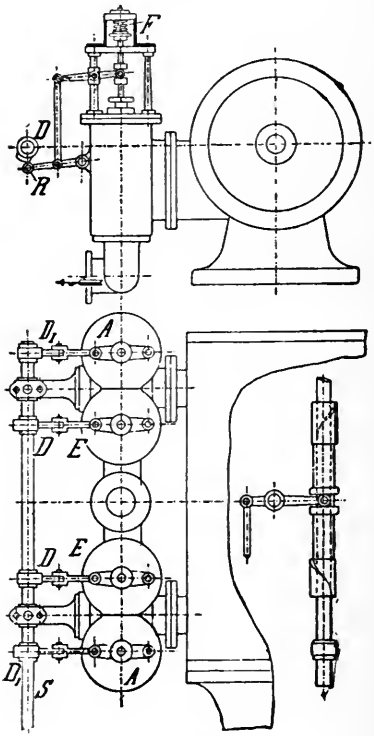



Fig. 768.

In figs. 767, 768,

A A, are the exhaust valves.
E E, the admission valves.
$D_1$ $D_1$, the cams for the exhaust valves.
D D, the cams for the admission valves.
S, the cam spindle.
R, the rollers at end of valve levers and resting on the cams.
F, the springs for closing the valves.

**Construction of the Cams** (Figs. 769—773).

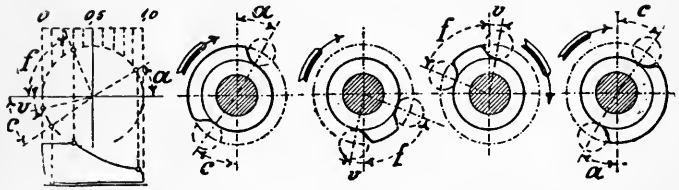


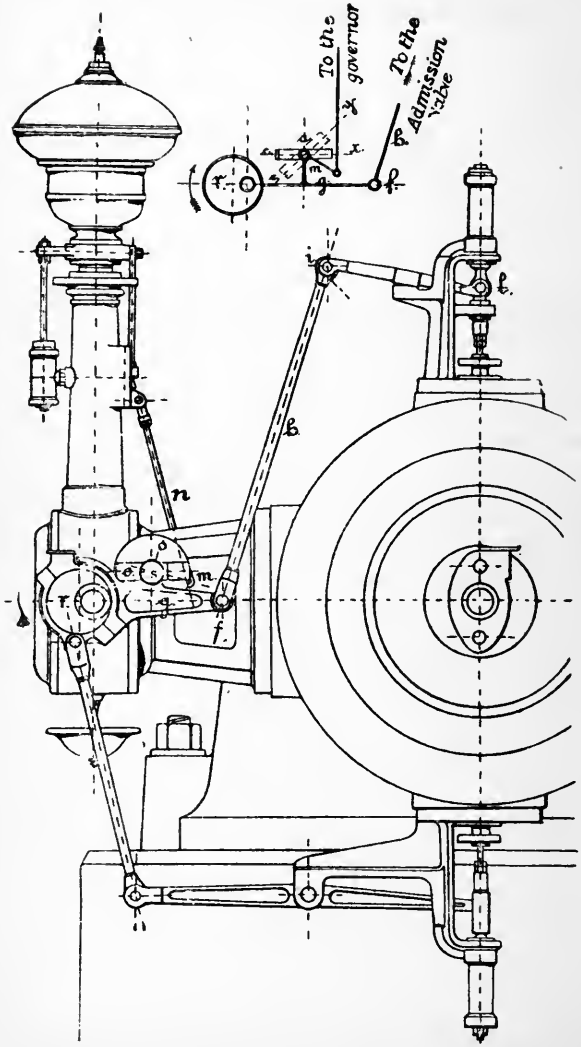

Fig 769. Fig. 770. Fig. 771. Fig. 772. Fig. 773.

Fig. 769.—Diagram.
Fig. 770.—Exhaust at left hand.
Fig. 771.—Admission at left hand.
Fig. 772.—Admission at right hand.
Fig. 773.—Exhaust at right hand.

In the diagram fig. 769, the cut-off is taken at ·3 then let

$v$ = the angle for lead. $f$ = the angle for cut-off.
$a$ = the angle for exhaust. $c$ = the angle for compression.

The cam spindle is shown in section, and the circle giving the position of rest and the half circle of the roller are drawn in. If the cut-off is to be varied either by hand or by the governor, both admission cams are made of screw form, and the cam spindle is moved lengthways to alter the cut-off.




Figs. 774, 775.

## Mushroom Valve Gear with Positive Motion to the Valves.

Hartung's Patent, made by the Harzer Co., Nordhausen, and the Buckau engine works, Magdeburg. Fig. 775.

The arrangement of this valve gear is as follows : an eccentric, *r*, with an elongated ring, *g*, is keyed on the valve shaft ; on the elongation of the eccentric ring is a pin, *s*, with a block which slides in the link, *c*, this link is moved as shown in dotted lines, figs. 774, 775, by means of the rod, *n*, in connection with the governor ; at the end of *g* is a pin, *f*, to which the rod, *b*, is attached ; the upper end of the rod, *b*, is attached to the lever, *i*, *h*, this lever being connected to the admission valve spindle, but resting only on the fulcrum bracket. In fig. 775, the engine is supposed to be at the dead point, and the valve open only to the extent of the lead, and the governor is at its lowest position corresponding to the latest cut-off, ·9 of the stroke ; the pin, *s*, is so arranged that the link may be moved without affecting the lead.

By the motion of the valve shaft when the engine is running, the eccentric moves in the direction of the arrow, and causes the end with the pin, *f*, to move up and down, thus opening and closing the valve by means of the rod, *b*, and lever, *i*, *h*. By this motion the pin, *s*, slides in the link, *c*, and if the governor rises, the link is turned from right to left, by means of the rod, *n*, and then the pin, *s*, is no longer guided in a horizontal but in an inclined direction, causing the path of the point, *f*, to be altered, and not to extend so far below the horizontal line during the opening of the valve ; this difference causes the valve to close sooner, and to give an earlier cut-off ; when the governor is at its highest position, the point, *f*, does not go below the horizontal line, and consequently there is no admission of steam.

**Widnmann's Patent Mushroom Valve Gear with Positive Motion to the Valves.**

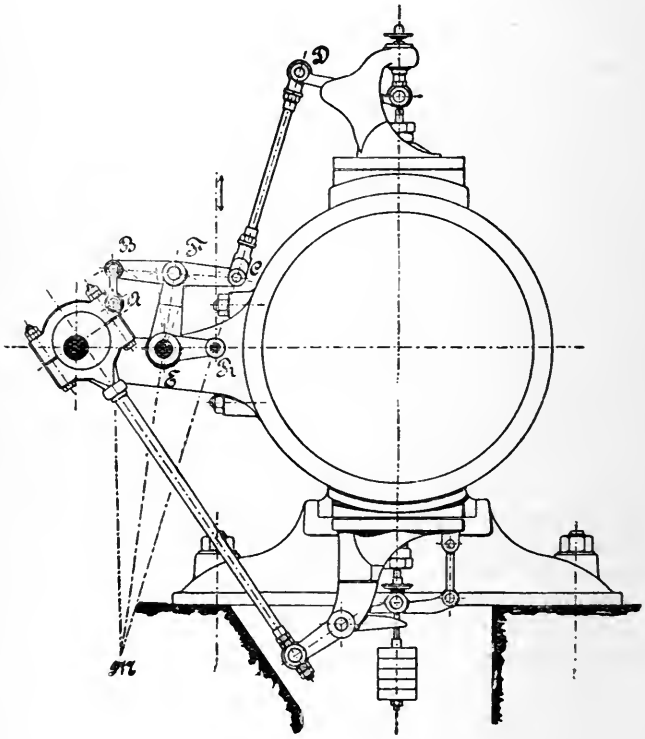



Fig. 776

**Mushroom Valve Gear with Positive Motion to Valves.**

H. Widnmann's Patent, Munich. Fig. 776.

The eccentric for giving motion to the valves in this gear is keyed on a side shaft, and has a long rod connected to a lever turning on a fixed point for working the exhaust valve; this renders any motion taken from the eccentric ring to be definite; a short pair of links, A B, fig. 776, are jointed to the upper side of the eccentric ring, and to the lever, B F C, and the rod, C D, gives motion to the admission valve through a rod and lever. The lever arm, E F, is keyed on a spindle, and this spindle is turned by the governor. By turning the spindle, E, a varying inclination is given to the arm, E F, and therefore also to the links, A B, and by this means the period during which the valve is open is altered, and an earlier or later cut-off obtained.

In order that the lead may be as nearly constant for all variations in the cut-off; the centre of the spindle, E, should be the centre of a circle, which approximately represents the path of the point, F.

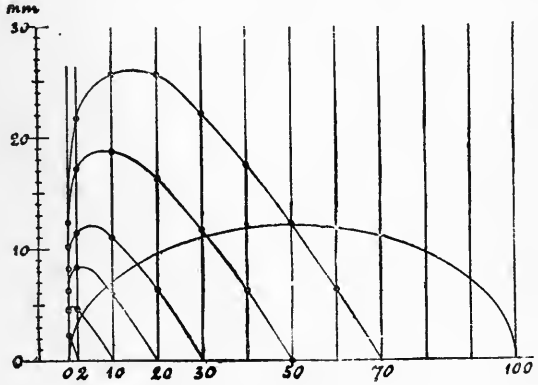



Fig. 777

**O. Recke's Patent Valve Gear.**

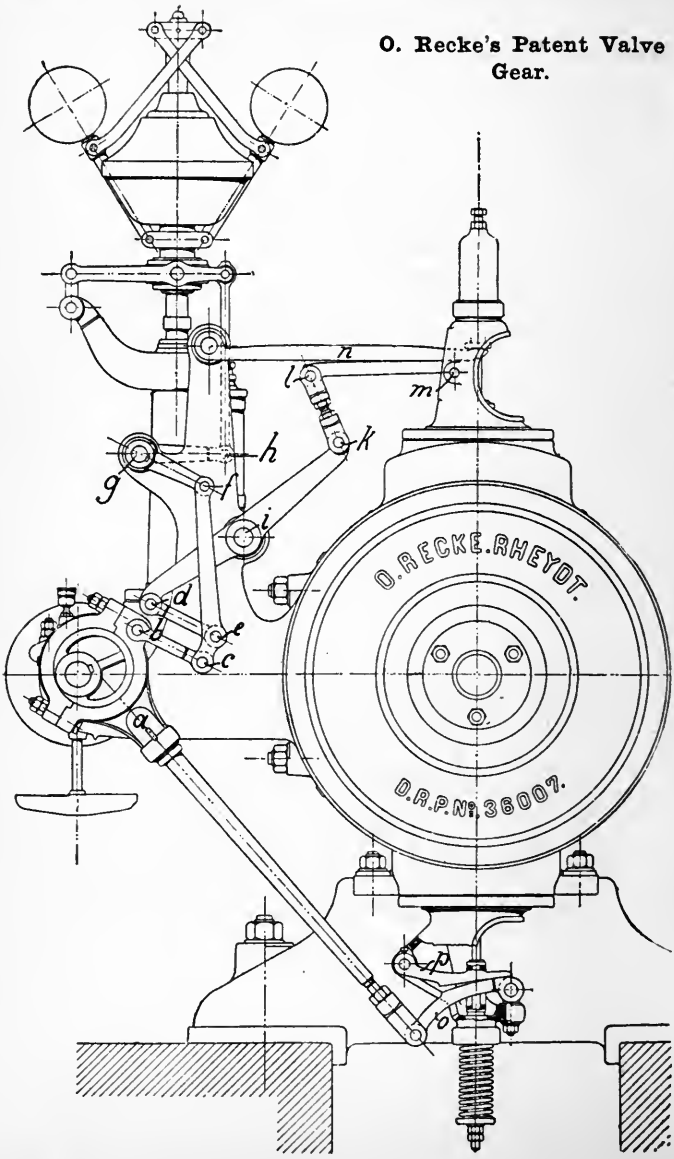



FIG. 778.

### Mushroom Valve Gear with Positive Motion to the Valves.

The eccentric, *a*, fig. 778, O. Recke's Patent, moves the exhaust valve by means of the roller levers, *o* and *p*, and the admission valve through the pin, *b*.

The governor lever, *g h*, turns on the pin, *g*, which also carries the lever, *g f*, the point *f* forms a turning point for the lever, *f e c*, connected to eccentric ring at *b*, by the rod *b c*, and also connected by *d e* to the lever *d i k*; at *k* this lever is connected with the upper lever, *l m n*, which moves the admission valve; *g f*, *d e*, and *b c*, are of equal length, and in the opening position of the valve parallel to one another.

This valve gear gives a very nearly constant lead, and a sufficient opening of the valves for the normal cut-off without excessive opening for the early cut-off, and very little back pressure on the governor.

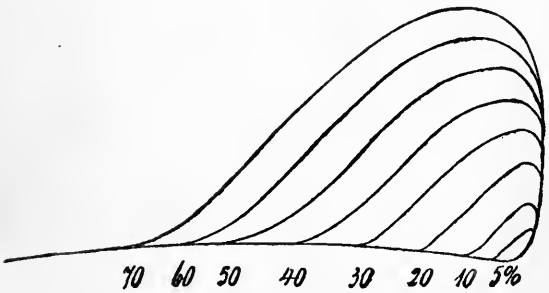
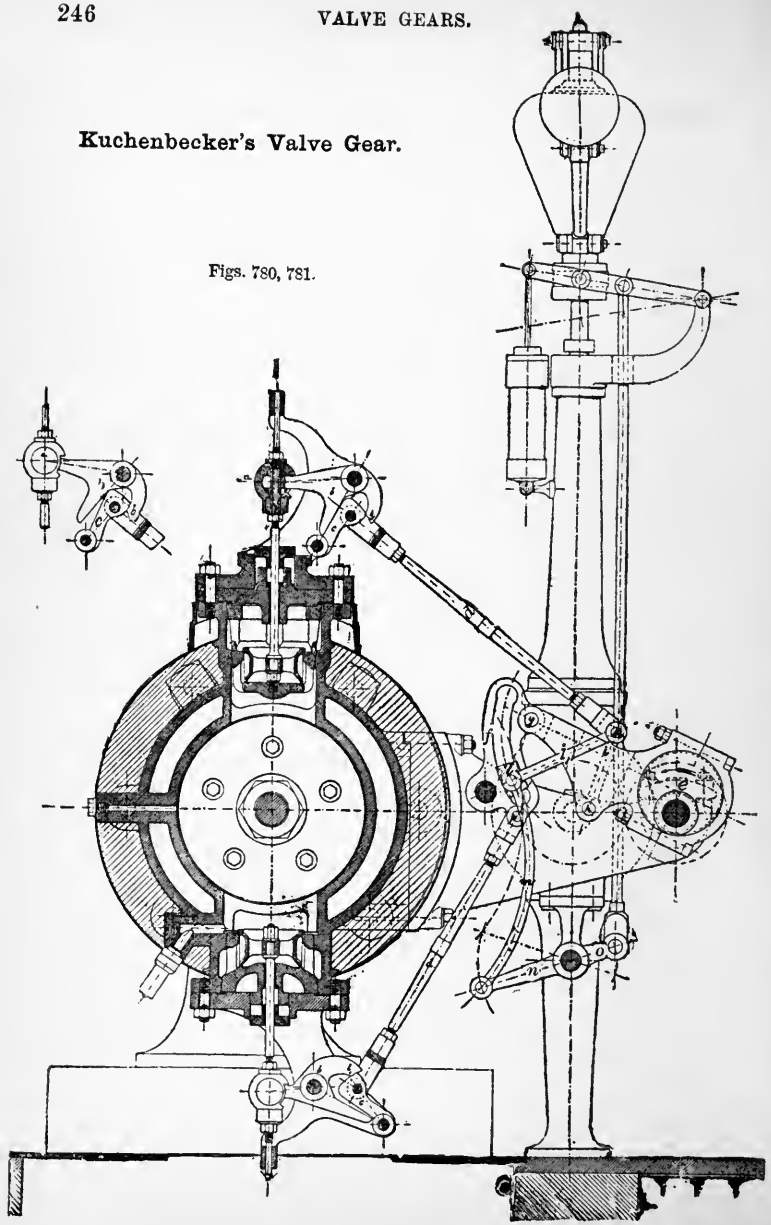



Fig 779.—Valve diagram, drawn by a model of the valve gear.

## Kuchenbecker's Valve Gear.

Figs. 780, 781.



## Kuchenbecker's Patent Mushroom Valve Gear with Positive Motion to the Valves.

The shaft, *e*, fig. 780, is turned in the direction of the arrow by gearing from the crank shaft, and carries an eccentric which gives a vibrating motion to the link, *f*. The sliding block, *l*, in this link, by means of the rods, $i_1$, *i*, and *d*, gives the necessary motion to the admission valve.

The double lever, *b*, $b_1$, communicates the motion by means of the arm, *c*, which is connected to the rod, *d*; the arm, *c*, acting against *b*, opens the valve, and acting against $b_1$, closes the valve; fig. 780 shows the position of the levers with the valve open, fig 781 with the valve closed. The rod, *d*, is connected to the link at *p*, for opening and closing the exhaust valve.

The governor alters the position of the block in the link, *f*, by means of the lever, *n o*, and the rod, *m*, and varies the cut-off.

The movement of the valves is very quick, and is positive, without the aid of dash pots or springs for either opening or closing.

**Proell's Patent Mushroom Valve Gear with Positive Motion to the Valves.**

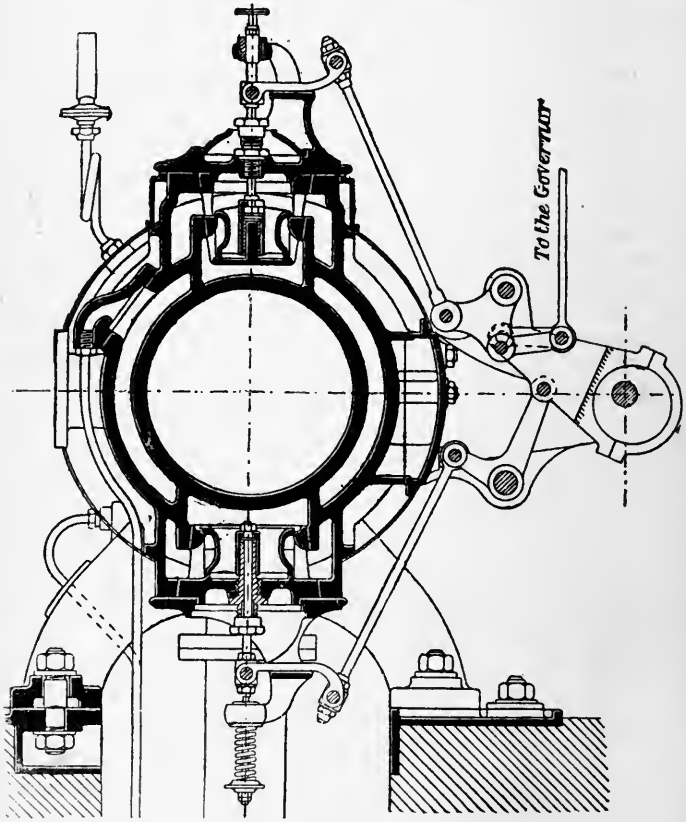



Fig. 782.

This gear consists essentially of valves driven by an eccentric ; a point in the eccentric ring moves in a closed curve, and by means of an adjustable lever connected to the governor the cut-off is varied ; by this peculiar motion the valves move with varying speed to and from their seatings, and open and close quietly. The exhaust valve is by levers attached to the eccentric ring, as shown in fig. 782

**E. König's Mushroom Valve Gear, with Positive Motion to the Valves.***

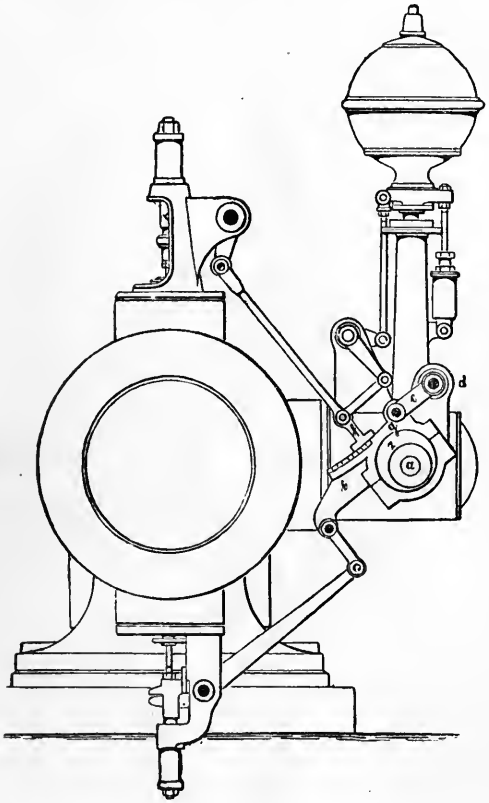



Fig. 783.

The eccentric ring in fig. 783 is made with a projection, *b*, and is jointed at *g* to an arm, *c*, which swings on a fixed point, *d*; the admission valve is moved by the rod, *f*, resting against the eccentric ring, *b*, the position of *f* is altered by the governor, and varies the cut-off

* Dingler's "Polytechnic Journal," No. 3, 1888.

**Gamerith's Patent Valve Gear, with Trip Arrangement by Stark & Hoffman, of Hirschberg.**

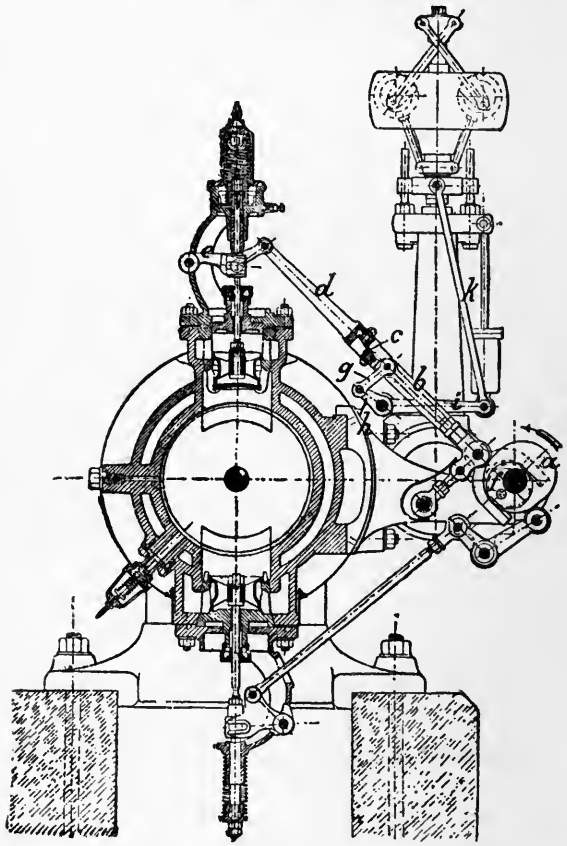



Fig. 784.

The valves in fig. 784 are worked by the cam, *a*, the admission valve is lifted by means of the catch, *c*, this slides away and allows the valve to fall at different positions determined by the governor, which raises the piece on which the catch acts by means of the rods *g*, *i* and *k*, and thus alters the cut-off. The exhaust valve is worked by the same cam, *a*.

**Sulzer's Valve Gear, with Trip Arrangement (Sulzer Bros., Winterthur).**

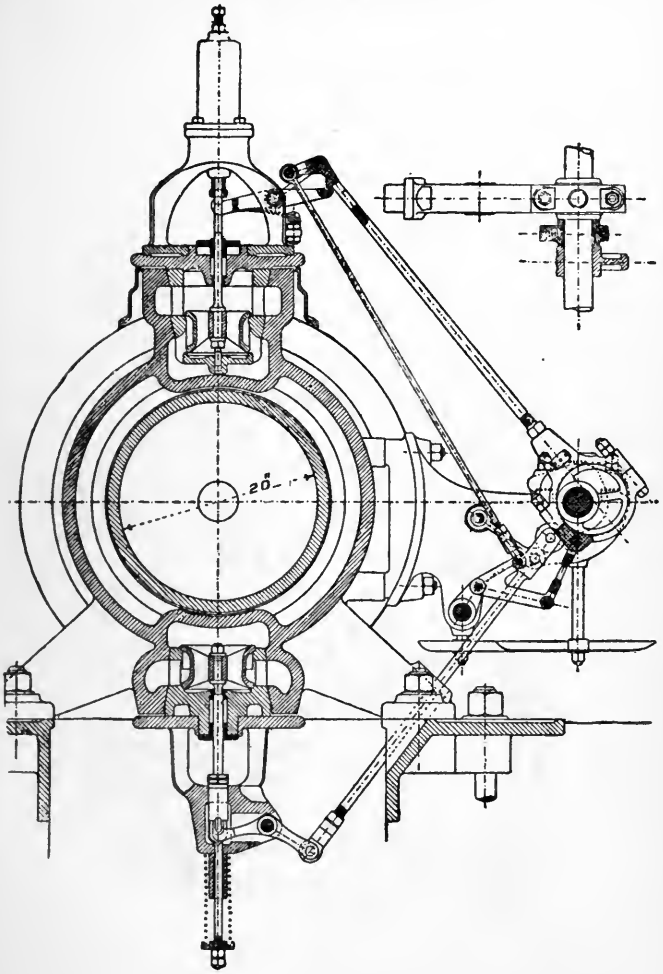
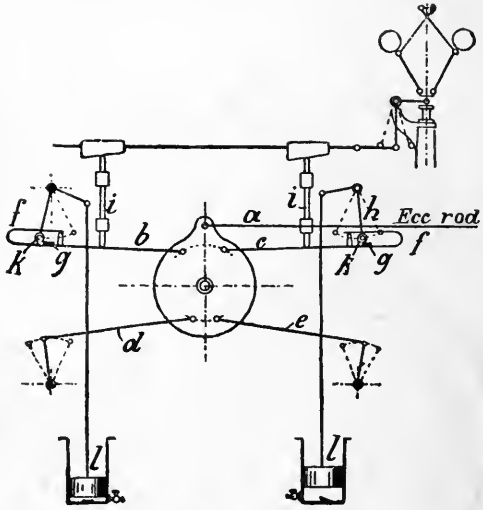



Fig. 785.

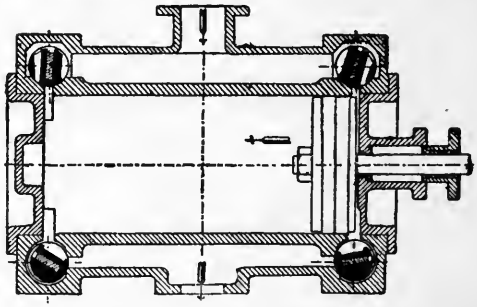
Fig. 785 shows the arrangement of valve gear by Sulzer, in which the valves are opened by an eccentric, and provided with trip gear by which they are allowed to close by means of a spring.

### Corliss Valve Gear.

The characteristics of the Corliss valve gear are, 1st, that there are two separate admission valves and two separate exhaust valves; 2ndly, that the admission valves are opened by an eccentric, then




Figs. 786, 787.



released and suddenly closed by either weights, springs, or dash pots; 3rdly, that the valves are cylindrical, and have a partial rotatory movement imparted to them.

The connection between the eccentric and the admission valve is generally in two parts, one being connected with the valve, the other

with the wrist plate, which receives its motion from the eccentric rod; during the opening of the valves the two parts are coupled, but to allow the valve to close the two parts are suddenly uncoupled.

The general action of the Corliss valve gear is shown in diagram in figs. 786, 787. The centre disc, or "wrist plate," receives an oscillating motion from the eccentric rod, *a*, the two rods, *b* and *c*, are formed into springs at *f*, *f*. The lever, *h*, is connected to the valve, the connection between the lever, *h*, and the rod, *c*, is by means of a kind of catch or detent arrangement, *k*, *g*, the governor acts by the rods, *i*, *i*; when the governor rises, the rods, *i*, *i*, are pushed down, and cause the catch to slip, leaving the lever, *h*, disconnected, and allowing the valve to be closed suddenly by dash pots, *l*, or by weights. The position of the governor determines the time of release.

**Harris' Corliss Valve Gear** (Figs. 788, 789).

This is an arrangement very much the same as above, but modified in the details, the rod, *a*, receives motion from the wrist plate, the short arm is free to turn on the valve spindle, *d*, at *g* is a small projection against which the curved arm, *f*, rests; the backward and forward motion of the rod, *a*, causes the *f* to slide against *g*, and according to the position of *g* (determined by the governor) depresses *f* and releases the catch, *e*, and thus allows the valve to be closed by the dash pot or weights.

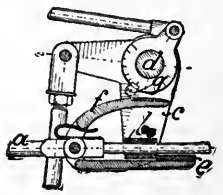



Fig. 788.

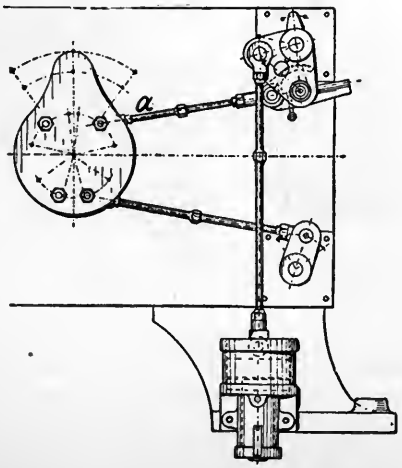



Fig. 789.

**Reynold's Corliss Valve Gear** (Fig. 790).

The arrangement is the same with respect to the general features as the original Corliss gear, the wrist plate receiving its motion from an eccentric. The lever, *c*, fig. 790, is loose on the valve spindle, *b*, and, together with *d*, is moved by the rod, *a*; from the wrist plate on *d* is a piece of steel, *e*, and on *e* the block *f* rests, this block is on lever *g*, latter being fast on the valve spindle *b*. The spring, *h*, serves to keep the forked lever, *d*, pressed up against *f*. Again, on the valve spindle, *b*, is the governor lever with the projection, I, against which by the motion the bell crank lever presses and thus releases the catch; if the governor ceases to act by the strap breaking, then the projection, *k*, releases the valve, and no more steam can enter the cylinder; the usual dash pot, or weight, for closing the valve is attached by the rod, *i*.

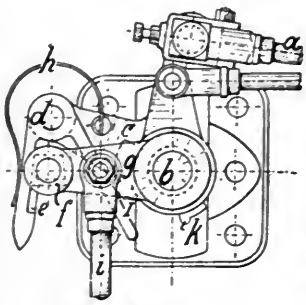


Fig. 790

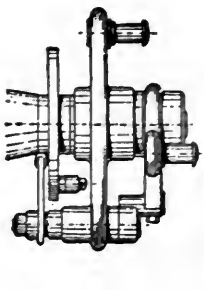


Fig 791.

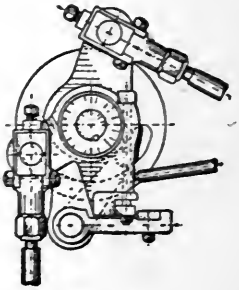


Fig. 792.

Figs. 791, 792 show an arrangement for obtaining the release of the valve without the use of springs. The releasing lever has a pin working in a groove on a disc adjustable by the governor.

**Wheelock Corliss Valve Gear** (Figs. 793, 794).

In this arrangement all the four ports are brought to the ends of the cylinder, the exhaust valves are driven direct from the wrist

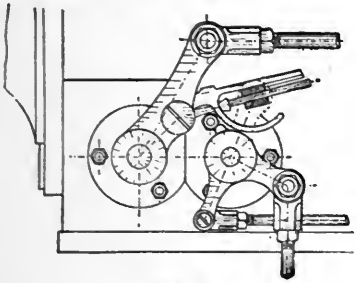


Fig. 793.

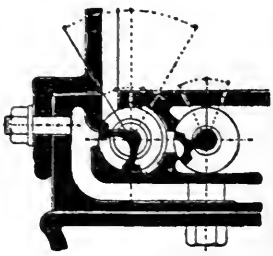


Fig. 794.

plate and are hollow, fig. 794. The admission valves act as expansion valves.

**Corliss Valve Gear, by J. R. Frikart, Paris** * (Fig. 795).

The exhaust valves are worked by the eccentric and levers as in fig. 795, and a five-armed lever takes the place of the wrist plate

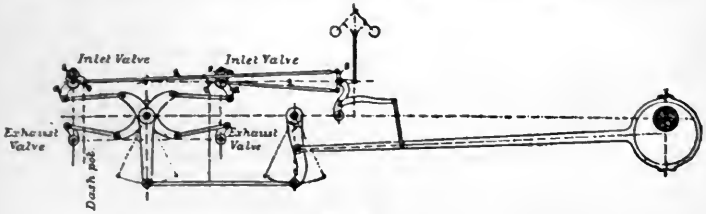



Fig. 795

in other types of Corliss gear The upper arms of this lever work on the double arms, A, A, these are free to turn on the bush which forms the bearing of the valve spindle, C, fig. 796. On C the tappet lever, D, D, is firmly fixed ; this lever, D, D, has on one side a plate of hardened steel, and on the other a joint and rod connected to the dash pot piston for closing the valve.

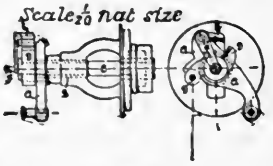



Fig 796.

* "Zeitschrift der Verein deutsch. Ingenieur," 1890, page 917.

Another tappet, E, is fixed to the short arm, F, fig. 796, which is free to turn on a pin fixed to A; a small rod connects the angle lever, H, with the eccentric rod, and at the upper end of H a small three-armed lever, I, is jointed; the rods, G, G, convey the motion from H to the arm F, which carries the tappet, E; by this motion E comes in contact with D, and opens the valve; the duration of the opening lasts until the inner edge of E escapes from the tappet D, then the valve closes. The governor is connected to the three-armed lever, I, and it will be seen from fig. 797 that the release will take place earlier or later according to the position of the lever, F, and with it the tappet, E, the alteration of position for the variation of cut-off being effected by the governor. The curves in chain dotted lines show the movement for the earliest and latest cut-off.

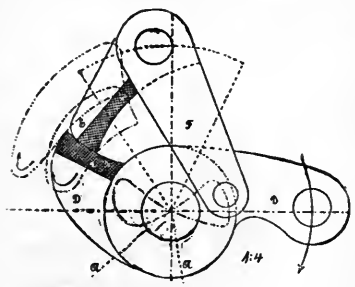


Fig. 797.

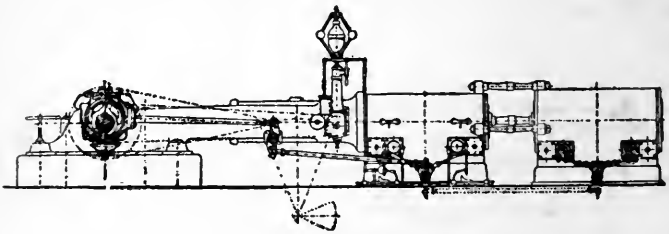


Fig. 798.—Corliss Engine by Thomas Powell, Rouen.*

Figures 798, 799, and 800, give examples of the general arrangement of Corliss gear by American and French engineers. With Corliss valves the length of the ports is very nearly equal to the diameter of the cylinder. The area of the ports is about ·07 of the piston area for the admission, and ·10 for the exhaust. The diameter of the valves is from ·25 to ·32 of the cylinder diameter.

* "Zeitschrift der Verein deutsch. Ingenieur," 1890 page 924

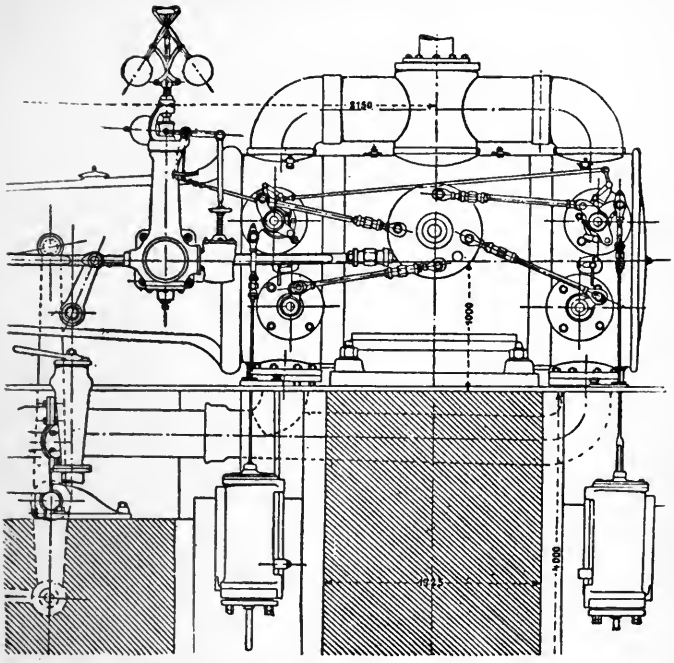


Fig. 799.—Corliss Engine by J. Farcot, St. Ouen.*

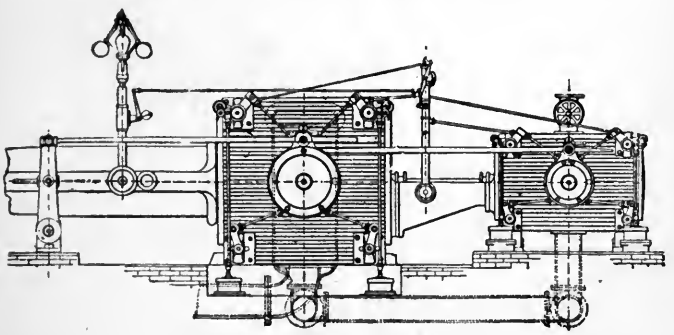
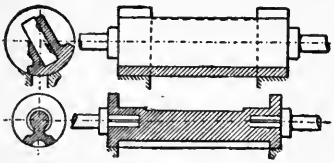


Fig. 800.—American Corliss Engine.†

* "Zeitschrift der Verein deutsch. Ingenieur," 1890, page 924.
† *Engineering*, 1891, page 750.

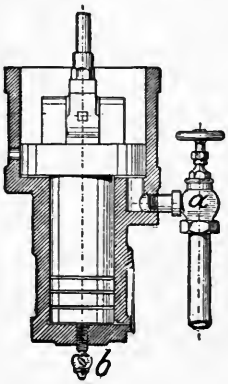
The valve spindles either pass through as in fig. 801, or are merely gudgeons as in fig. 802; the ends of the rods are provided with adjustments to take up wear.



Figs. 801, 802.

The dash pots, figs. 803, 804, have working cylinders about ·6 to ·5 of the diameter of the engine cylinder, and the dash pot proper about ·4 to ·3 of the cylinder diameter. Small adjustable valves are provided at *a* and *b*, to regulate the action of both pistons; the arrangement shown in fig. 804 has

Fig. 803.



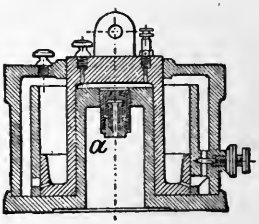




Fig. 804.

the advantage of being noiseless in action, but is not so cheap to make as that shown in fig. 803.

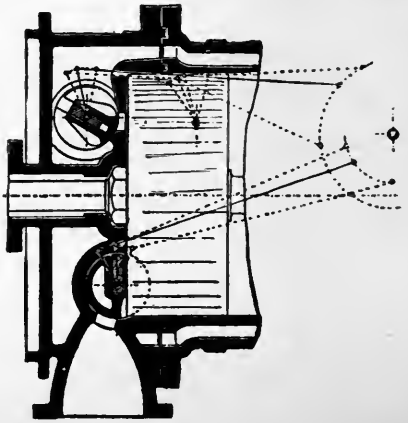


Fig. 805.—Section through end of cylinder showing arrangement of Corliss valves, by J. Farcot Bros.

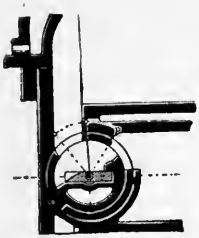


Fig. 806.—Section of Corliss valve, by Douglas & Grant, Kirkcaldy.

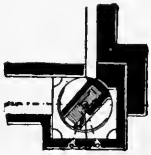
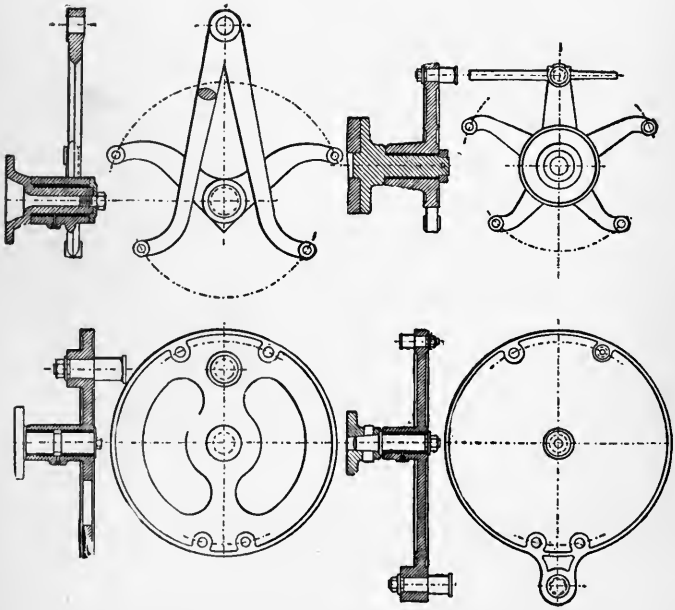
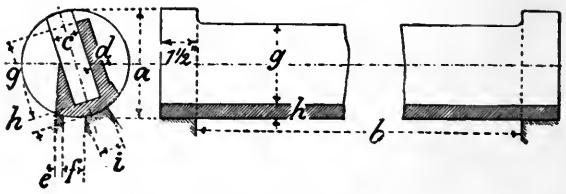


Fig. 807.—Section of Corliss valve by the Sangerhauser Engine Works.



Figs. 808—815.—Various designs for wrist-plates and multiple-armed levers for Corliss gear

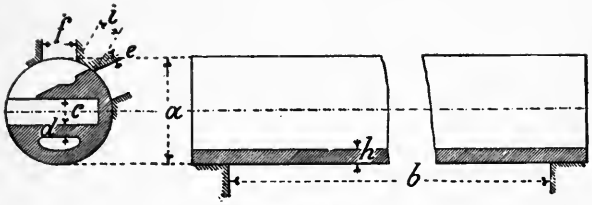



Figs. 816, 817.—Sections of Corliss Valves.

TABLE 69.—**Dimensions of Corliss Valves** (Figs. 816, 817).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* |
|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $4\frac{1}{2}$ | $14\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{5}{16}$ | $\frac{7}{8}$ | $3\frac{1}{4}$ | $\frac{3}{4}$ | 1 |
| 48 | 18 | 5 | $16\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{3}{8}$ | $\frac{15}{16}$ | $3\frac{7}{8}$ | $\frac{3}{4}$ | $1\frac{1}{8}$ |
| 48 | 20 | $5\frac{1}{2}$ | $18\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $1\frac{1}{16}$ | $4\frac{1}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ |
| 54 | 22 | 6 | 21 | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{7}{16}$ | $1\frac{1}{8}$ | $4\frac{5}{8}$ | $\frac{7}{8}$ | $1\frac{3}{8}$ |
| 54 | 24 | $6\frac{1}{2}$ | 23 | $1\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $1\frac{3}{16}$ | 5 | $\frac{7}{8}$ | $1\frac{1}{2}$ |
| 54 | 26 | 7 | 25 | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{9}{16}$ | $1\frac{3}{8}$ | $5\frac{3}{8}$ | $\frac{7}{8}$ | $1\frac{5}{8}$ |
| 60 | 28 | $7\frac{1}{2}$ | 27 | $1\frac{7}{8}$ | 1 | $\frac{5}{8}$ | $1\frac{1}{2}$ | $5\frac{3}{4}$ | 1 | $1\frac{3}{4}$ |
| 60 | 30 | $8\frac{1}{2}$ | 29 | 2 | 1 | $\frac{3}{4}$ | $1\frac{15}{16}$ | $6\frac{3}{8}$ | 1 | $1\frac{7}{8}$ |

All Dimensions are given in Inches.

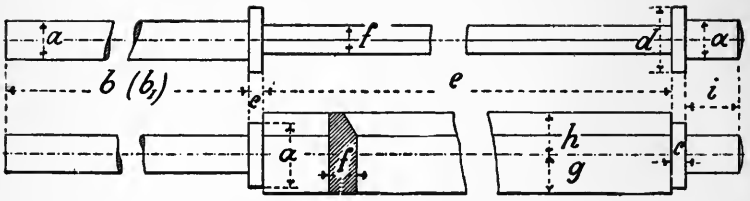



Figs. 818, 819.—Sections of Corliss Valves.

TABLE 70.—**Dimensions of Corliss Valves** (Figs. 818, 819).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *h* | *i* |
|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $4\frac{1}{2}$ | $14\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $\frac{1}{8}$ | $1\frac{7}{16}$ | $\frac{3}{4}$ | 1 |
| 48 | 18 | 5 | $16\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{3}{16}$ | $1\frac{9}{16}$ | $\frac{3}{4}$ | $1\frac{1}{8}$ |
| 48 | 20 | $5\frac{1}{2}$ | $18\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{3}{16}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ |
| 54 | 22 | 6 | 21 | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{3}{16}$ | $1\frac{7}{8}$ | $\frac{7}{8}$ | $1\frac{3}{8}$ |
| 54 | 24 | $6\frac{1}{2}$ | 23 | $1\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | 2 | $\frac{7}{8}$ | $1\frac{1}{2}$ |
| 54 | 26 | 7 | 25 | $1\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{1}{4}$ | $2\frac{1}{8}$ | $\frac{7}{8}$ | $1\frac{5}{8}$ |
| 60 | 28 | $7\frac{1}{2}$ | 27 | $1\frac{7}{8}$ | 1 | $\frac{1}{4}$ | $2\frac{5}{16}$ | 1 | $1\frac{3}{4}$ |
| 60 | 30 | $8\frac{1}{2}$ | 29 | 2 | 1 | $\frac{5}{16}$ | $2\frac{1}{2}$ | 1 | $1\frac{7}{8}$ |

All Dimensions are given in Inches.




Figs. 820, 821.—Corliss Valve Spindles.

TABLE 71.—**Dimensions of Corliss Valve Spindles**
(Figs. 820, 821).

| H | D | $a$ | $b$ | $b_1$ | $c$ | $d$ | $e$ | $f$ | $g$ | $h$ | $i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $1\frac{1}{2}$ | $15\frac{7}{8}$ | $11\frac{3}{8}$ | $\frac{1}{2}$ | $2\frac{5}{8}$ | $17\frac{1}{2}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{1}{4}$ |
| 48 | 18 | $1\frac{5}{8}$ | $17\frac{1}{8}$ | $12\frac{1}{8}$ | $\frac{5}{8}$ | $2\frac{3}{4}$ | $19\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $2\frac{1}{2}$ |
| 48 | 20 | $1\frac{3}{4}$ | $18\frac{3}{4}$ | $13\frac{1}{4}$ | $\frac{5}{8}$ | $2\frac{7}{8}$ | $21\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{7}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ |
| 54 | 22 | $1\frac{7}{8}$ | $19\frac{3}{4}$ | 14 | $\frac{3}{4}$ | 3 | 24 | $1\frac{1}{2}$ | 2 | $2\frac{5}{8}$ | 3 |
| 54 | 24 | 2 | $20\frac{3}{4}$ | $14\frac{3}{4}$ | $\frac{3}{4}$ | $3\frac{1}{4}$ | 26 | $1\frac{5}{8}$ | $2\frac{1}{4}$ | $2\frac{3}{4}$ | $3\frac{1}{4}$ |
| 54 | 26 | $2\frac{1}{8}$ | $21\frac{3}{4}$ | $15\frac{1}{2}$ | $\frac{7}{8}$ | $3\frac{1}{2}$ | 28 | $1\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{7}{8}$ | $3\frac{1}{2}$ |
| 60 | 28 | $2\frac{1}{4}$ | $22\frac{3}{4}$ | $16\frac{1}{4}$ | $\frac{7}{8}$ | $3\frac{5}{8}$ | 30 | $1\frac{7}{8}$ | $2\frac{5}{8}$ | $3\frac{1}{8}$ | $3\frac{7}{8}$ |
| 60 | 30 | $2\frac{3}{8}$ | 24 | 17 | 1 | $3\frac{3}{4}$ | 32 | 2 | $3\frac{1}{8}$ | $3\frac{1}{4}$ | $4\frac{1}{4}$ |

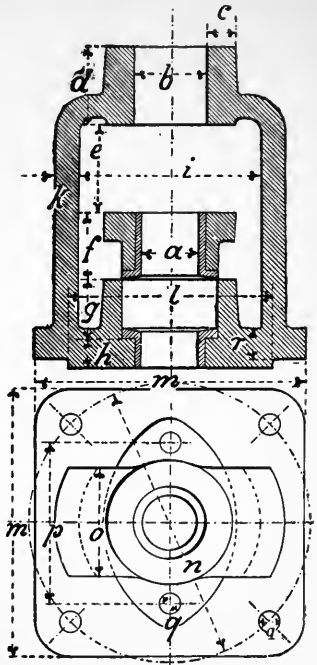
All Dimensions are given in Inches.

$b$ for admission valves.
$b_1$ for exhaust valves.

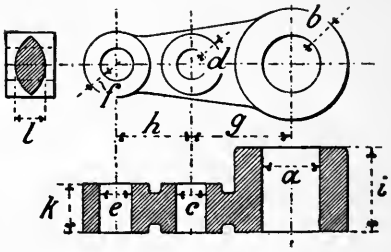
TABLE 72.—**Dimensions of Glands and Brackets for Corliss Valve Spindles.**

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $1\frac{1}{2}$ | $1\frac{7}{8}$ | $\frac{13}{16}$ | $1\frac{7}{8}$ | $3\frac{1}{2}$ | $1\frac{1}{2}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $5\frac{1}{2}$ | $\frac{9}{16}$ | $4\frac{7}{8}$ | 7 | $7\frac{1}{8}$ | $2\frac{7}{8}$ | $4\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{3}{4}$ |
| 48 | 18 | $1\frac{5}{8}$ | 2 | $\frac{7}{8}$ | 2 | $3\frac{1}{2}$ | $1\frac{3}{4}$ | $1\frac{5}{8}$ | $\frac{3}{4}$ | 6 | $\frac{5}{8}$ | $5\frac{3}{8}$ | $7\frac{1}{2}$ | $7\frac{5}{8}$ | 3 | $5\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{13}{16}$ |
| 48 | 20 | $1\frac{3}{4}$ | $2\frac{1}{4}$ | $\frac{15}{16}$ | $2\frac{1}{4}$ | $3\frac{5}{8}$ | $1\frac{7}{8}$ | $1\frac{7}{8}$ | $\frac{7}{8}$ | $6\frac{1}{2}$ | $\frac{11}{16}$ | $5\frac{7}{8}$ | 8 | $8\frac{1}{4}$ | $3\frac{1}{4}$ | $5\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{15}{16}$ |
| 54 | 22 | $1\frac{7}{8}$ | $2\frac{3}{8}$ | 1 | $2\frac{1}{2}$ | $3\frac{5}{8}$ | 2 | 2 | 1 | $6\frac{3}{4}$ | $\frac{3}{4}$ | $6\frac{3}{8}$ | $8\frac{1}{2}$ | $8\frac{7}{8}$ | $3\frac{1}{2}$ | $5\frac{1}{2}$ | $\frac{3}{4}$ | 1 |
| 54 | 24 | 2 | $2\frac{5}{8}$ | $1\frac{1}{16}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $2\frac{1}{4}$ | $2\frac{1}{8}$ | 1 | 7 | $\frac{13}{16}$ | $6\frac{7}{8}$ | $9\frac{1}{4}$ | $9\frac{5}{8}$ | $3\frac{3}{4}$ | $5\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{1}{16}$ |
| 54 | 26 | $2\frac{1}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{8}$ | $2\frac{7}{8}$ | $3\frac{3}{4}$ | $2\frac{3}{8}$ | $2\frac{1}{4}$ | $1\frac{1}{8}$ | $7\frac{1}{4}$ | $\frac{7}{8}$ | $7\frac{3}{8}$ | 10 | $10\frac{1}{4}$ | 4 | 6 | $\frac{7}{8}$ | $1\frac{1}{8}$ |
| 60 | 28 | $2\frac{1}{4}$ | 3 | $1\frac{3}{16}$ | 3 | $3\frac{3}{4}$ | $2\frac{5}{8}$ | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $7\frac{1}{2}$ | $\frac{15}{16}$ | $7\frac{7}{8}$ | $10\frac{5}{8}$ | 11 | $4\frac{1}{4}$ | $6\frac{1}{4}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ |
| 60 | 30 | $2\frac{3}{8}$ | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | $7\frac{3}{4}$ | 1 | $8\frac{7}{8}$ | $11\frac{1}{4}$ | $11\frac{3}{4}$ | $4\frac{1}{2}$ | $6\frac{1}{2}$ | $\frac{7}{8}$ | $1\frac{5}{16}$ |

All Dimensions are given in Inches.




Figs. 822, 823. – Brackets and Glands for Corliss Valve Spindles.

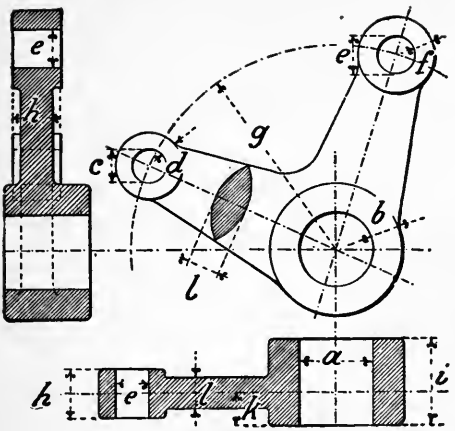



Figs. 824—826.—Lever Arms for Corliss Valves.

TABLE 73.—**Dimensions of Lever Arms for Corliss Valves** (Figs. 824—826).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $1\frac{1}{2}$ | $\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{3}{8}$ | $\frac{15}{16}$ | $\frac{7}{16}$ | $2\frac{3}{4}$ | 2 | $2\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{13}{16}$ |
| 48 | 18 | $1\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{16}$ | 1 | $\frac{1}{2}$ | 3 | $2\frac{1}{8}$ | $2\frac{1}{2}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ |
| 48 | 20 | $1\frac{3}{4}$ | $\frac{13}{16}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $1\frac{1}{16}$ | $\frac{9}{16}$ | $3\frac{1}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{15}{16}$ |
| 54 | 22 | $1\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{9}{16}$ | $3\frac{3}{8}$ | $2\frac{1}{2}$ | $2\frac{7}{8}$ | $1\frac{5}{8}$ | 1 |
| 54 | 24 | 2 | $\frac{15}{16}$ | $\frac{15}{16}$ | $\frac{9}{16}$ | $1\frac{3}{16}$ | $\frac{5}{8}$ | $3\frac{1}{2}$ | $2\frac{5}{8}$ | 3 | $1\frac{3}{4}$ | $1\frac{1}{16}$ |
| 54 | 26 | $2\frac{1}{8}$ | 1 | 1 | $\frac{9}{16}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $3\frac{3}{4}$ | $2\frac{3}{4}$ | $3\frac{1}{8}$ | $1\frac{3}{4}$ | $1\frac{1}{8}$ |
| 60 | 28 | $2\frac{1}{4}$ | $1\frac{1}{16}$ | $1\frac{1}{16}$ | $\frac{5}{8}$ | $1\frac{5}{16}$ | $\frac{11}{16}$ | 4 | 3 | $3\frac{1}{4}$ | $1\frac{7}{8}$ | $1\frac{3}{16}$ |
| 60 | 30 | $2\frac{3}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{8}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{11}{16}$ | $4\frac{1}{8}$ | $3\frac{1}{8}$ | $3\frac{1}{2}$ | 2 | $1\frac{1}{4}$ |

All Dimensions are given in Inches.




Figs. 827—829. Levers for Corliss Valves.

TABLE 74.—**Dimensions of Levers for Corliss Valves** (Figs. 827—829).

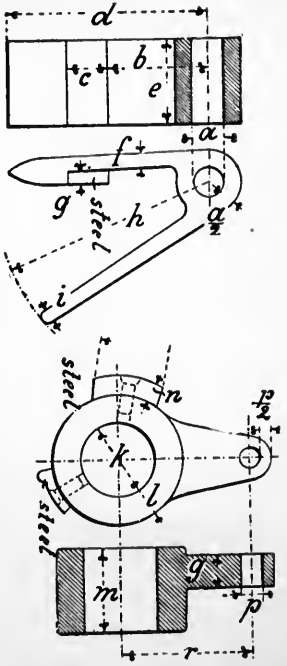
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $1\frac{7}{8}$ | $\frac{13}{16}$ | $\frac{13}{16}$ | $\frac{7}{16}$ | $\frac{15}{16}$ | $\frac{1}{2}$ | $5\frac{1}{4}$ | $1\frac{1}{8}$ | $2\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{13}{16}$ |
| 48 | 18 | 2 | $\frac{7}{8}$ | $\frac{7}{8}$ | $\frac{7}{16}$ | 1 | $\frac{1}{2}$ | $5\frac{1}{2}$ | $1\frac{1}{4}$ | $2\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{7}{8}$ |
| 48 | 20 | $2\frac{1}{4}$ | $\frac{15}{16}$ | $\frac{15}{16}$ | $\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{9}{16}$ | 6 | $1\frac{3}{8}$ | $2\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{15}{16}$ |
| 54 | 22 | $2\frac{3}{8}$ | 1 | 1 | $\frac{1}{2}$ | $1\frac{1}{8}$ | $\frac{9}{16}$ | $6\frac{1}{2}$ | $1\frac{1}{2}$ | $2\frac{7}{8}$ | 1 | 1 |
| 54 | 24 | $2\frac{5}{8}$ | $1\frac{1}{16}$ | 1 | $\frac{1}{2}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | 7 | $1\frac{5}{8}$ | 3 | $1\frac{1}{8}$ | $1\frac{1}{16}$ |
| 54 | 26 | $2\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{8}$ | $\frac{9}{16}$ | $1\frac{5}{16}$ | $\frac{5}{8}$ | $7\frac{1}{2}$ | $1\frac{3}{4}$ | $3\frac{1}{8}$ | $1\frac{1}{8}$ | $1\frac{1}{8}$ |
| 60 | 28 | 3 | $1\frac{3}{16}$ | $1\frac{3}{16}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | $\frac{11}{16}$ | 8 | $1\frac{7}{8}$ | $3\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{13}{16}$ |
| 60 | 30 | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | $\frac{3}{4}$ | $8\frac{1}{2}$ | 2 | $3\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ |

All Dimensions are given in Inches.

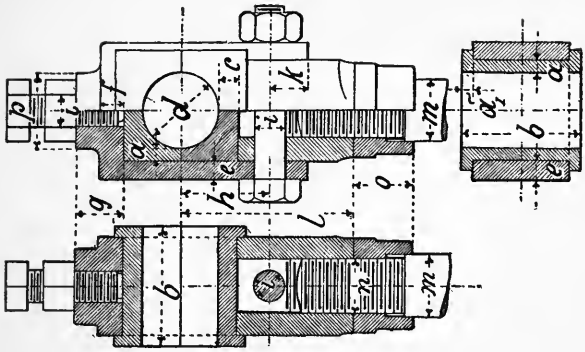
TABLE 75.—**Dimensions of Trip-gear Levers for Corliss Valves** (Figs. 830—833).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *p* | *r* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | $\frac{7}{8}$ | $2\frac{5}{8}$ | 1 | $5\frac{1}{8}$ | $2\frac{1}{4}$ | $\frac{7}{16}$ | $\frac{5}{16}$ | $5\frac{5}{8}$ | $\frac{5}{16}$ | $1\frac{7}{8}$ | $\frac{13}{16}$ | $2\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $3\frac{1}{2}$ |
| 48 | 18 | $\frac{15}{16}$ | $2\frac{7}{8}$ | $1\frac{1}{8}$ | $5\frac{5}{8}$ | $2\frac{1}{2}$ | $\frac{7}{16}$ | $\frac{5}{16}$ | $6\frac{1}{8}$ | $\frac{5}{16}$ | 2 | $\frac{7}{8}$ | $2\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{5}{8}$ | $3\frac{3}{4}$ |
| 48 | 20 | 1 | $3\frac{1}{8}$ | $1\frac{1}{4}$ | 6 | $2\frac{3}{4}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $6\frac{5}{8}$ | $\frac{3}{8}$ | $2\frac{1}{4}$ | $\frac{5}{16}$ | $2\frac{3}{4}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | 4 |
| 54 | 22 | $1\frac{1}{16}$ | $3\frac{3}{8}$ | $1\frac{1}{4}$ | $6\frac{1}{2}$ | $2\frac{7}{8}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | 7 | $\frac{3}{8}$ | $2\frac{3}{8}$ | 1 | $2\frac{7}{8}$ | $\frac{11}{16}$ | $\frac{3}{4}$ | $4\frac{1}{4}$ |
| 54 | 24 | $1\frac{1}{8}$ | $3\frac{5}{8}$ | $1\frac{3}{8}$ | $6\frac{7}{8}$ | 3 | $\frac{9}{16}$ | $\frac{7}{16}$ | $7\frac{1}{2}$ | $\frac{7}{16}$ | $2\frac{5}{8}$ | $1\frac{1}{16}$ | 3 | $\frac{3}{4}$ | $\frac{3}{4}$ | $4\frac{1}{2}$ |
| 54 | 26 | $1\frac{1}{4}$ | $3\frac{3}{4}$ | $1\frac{3}{8}$ | $7\frac{1}{4}$ | $3\frac{1}{8}$ | $\frac{9}{16}$ | $\frac{7}{16}$ | 8 | $\frac{7}{16}$ | $2\frac{3}{4}$ | $1\frac{1}{8}$ | $3\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $4\frac{3}{4}$ |
| 60 | 28 | $1\frac{5}{16}$ | 4 | $1\frac{1}{2}$ | $7\frac{3}{4}$ | $3\frac{1}{4}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $8\frac{1}{2}$ | $\frac{1}{2}$ | 3 | $1\frac{5}{16}$ | $3\frac{1}{4}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | 5 |
| 60 | 30 | $1\frac{3}{8}$ | $4\frac{1}{4}$ | $1\frac{1}{2}$ | $8\frac{1}{4}$ | $3\frac{1}{2}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | 9 | $\frac{1}{2}$ | $3\frac{1}{8}$ | $1\frac{1}{4}$ | $3\frac{1}{2}$ | $\frac{7}{8}$ | $\frac{7}{8}$ | $5\frac{1}{2}$ |

All Dimensions are given in Inches.




Figs. 830–833.—Trip gear levers for Corliss valves.

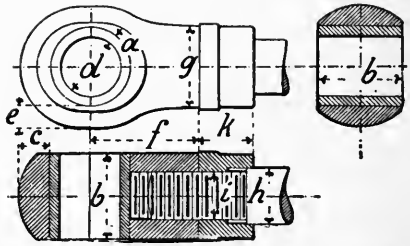


Figs. 834—836. – Valve Rod-End for Corliss Valves.

TABLE 76.—**Dimensions of Valve Rod-Ends for Corliss Valves** (Figs. 834—836).

| $d$ | $b$ | $a$ | $a_1$ | $c$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ | $m$ | $n$ | $o$ | $p$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $1\frac{1}{2}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{5}{8}$ | $1\frac{1}{4}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $1\frac{1}{4}$ |
| $1\frac{1}{16}$ | $1\frac{5}{8}$ | $\frac{1}{8}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{1}{4}$ | $\frac{5}{16}$ | $\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $2\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $1\frac{1}{4}$ |
| $1\frac{3}{16}$ | $1\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | $\frac{3}{4}$ | $1\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $2\frac{3}{4}$ | 1 | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ |
| $1\frac{1}{4}$ | $1\frac{7}{8}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | $\frac{3}{4}$ | $1\frac{1}{2}$ | $\frac{1}{2}$ | $\frac{5}{8}$ | $2\frac{7}{8}$ | 1 | $\frac{7}{8}$ | 1 | $1\frac{1}{4}$ |
| $1\frac{3}{8}$ | 2 | $\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{5}{16}$ | $\frac{5}{16}$ | $\frac{7}{16}$ | $\frac{3}{4}$ | $1\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $3\frac{1}{8}$ | $1\frac{1}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{2}$ |
| $1\frac{7}{16}$ | $2\frac{1}{8}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $3\frac{1}{4}$ | $1\frac{1}{8}$ | 1 | $1\frac{1}{8}$ | $1\frac{1}{2}$ |
| $1\frac{1}{2}$ | $2\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | $\frac{7}{8}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $3\frac{3}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ |
| $1\frac{5}{8}$ | $2\frac{1}{2}$ | $\frac{1}{4}$ | $\frac{1}{4}$ | $\frac{3}{8}$ | $\frac{3}{8}$ | $\frac{1}{2}$ | 1 | $1\frac{7}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{8}$ | $1\frac{1}{4}$ | $1\frac{1}{2}$ |

All Dimensions are given in Inches.




Figs. 837—839.—Valve Rod-End for Corliss Valves.

TABLE 77.—**Dimensions of Valve Rod-Ends for Corliss Valves** (Figs. 837—839).

| *d* | *b* | *a* | *c* | *e* | *f* | *g* | *h* | *i* | *k* |
|---|---|---|---|---|---|---|---|---|---|
| $\frac{3}{4}$ | $1\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | $1\frac{3}{8}$ | $1\frac{1}{16}$ | $\frac{5}{8}$ | $\frac{1}{2}$ | $\frac{5}{8}$ |
| $\frac{7}{8}$ | $1\frac{1}{8}$ | $\frac{1}{8}$ | $\frac{3}{8}$ | $\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{1}{16}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ |
| $\frac{15}{16}$ | $1\frac{1}{4}$ | $\frac{1}{8}$ | $\frac{7}{16}$ | $\frac{5}{16}$ | $1\frac{3}{8}$ | $1\frac{1}{8}$ | $\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ |
| 1 | $1\frac{7}{16}$ | $\frac{1}{8}$ | $\frac{7}{16}$ | $\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ |
| $1\frac{1}{16}$ | $1\frac{1}{2}$ | $\frac{5}{32}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | $1\frac{7}{8}$ | $1\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ |
| $1\frac{1}{8}$ | $1\frac{1}{2}$ | $\frac{3}{16}$ | $\frac{1}{2}$ | $\frac{3}{8}$ | 2 | $1\frac{3}{8}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | $\frac{7}{8}$ |
| $1\frac{3}{16}$ | $1\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{9}{16}$ | $\frac{7}{16}$ | $2\frac{1}{4}$ | $1\frac{5}{8}$ | 1 | $\frac{7}{8}$ | 1 |
| $1\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{3}{16}$ | $\frac{5}{8}$ | $\frac{7}{16}$ | $2\frac{3}{8}$ | $1\frac{5}{8}$ | 1 | $\frac{7}{8}$ | 1 |

All Dimensions are given in Inches.

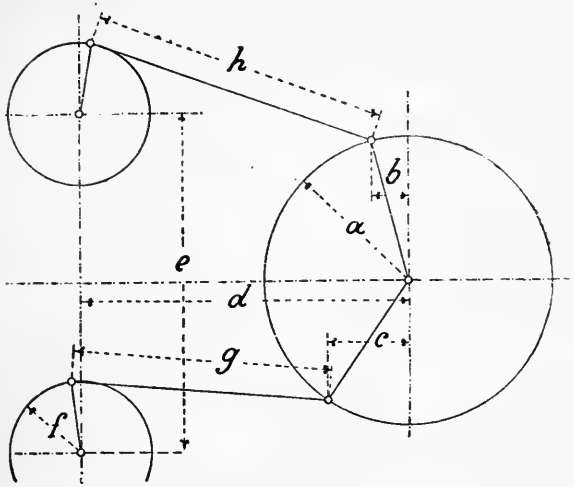
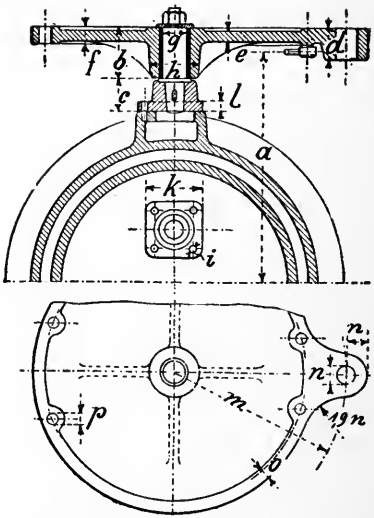



Fig. 840.—Diagram showing Centres of Valve Rods for Corliss Valve Gear.

TABLE 78.—**Dimensions of Centres of Valve Rods for Corliss Valve Gear** (Fig. 840).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* |
|---|---|---|---|---|---|---|---|---|---|
| 48 | 16 | 10 | $3\frac{1}{4}$ | $4\frac{1}{4}$ | 27 | $23\frac{1}{2}$ | $5\frac{1}{4}$ | $23\frac{1}{2}$ | $23\frac{3}{4}$ |
| 48 | 18 | 11 | $3\frac{1}{4}$ | $4\frac{1}{2}$ | $27\frac{1}{4}$ | $25\frac{1}{2}$ | $5\frac{1}{2}$ | $23\frac{1}{2}$ | $24\frac{1}{2}$ |
| 48 | 20 | 12 | $3\frac{3}{8}$ | $4\frac{3}{4}$ | $27\frac{1}{2}$ | $28\frac{1}{4}$ | 6 | $21\frac{1}{2}$ | 25 |
| 54 | 22 | 13 | $3\frac{1}{2}$ | 5 | $30\frac{3}{4}$ | $30\frac{1}{2}$ | $6\frac{1}{2}$ | $28\frac{1}{4}$ | 27 |
| 54 | 24 | 14 | $3\frac{7}{8}$ | $5\frac{3}{8}$ | 31 | $33\frac{1}{2}$ | 7 | $26\frac{1}{4}$ | $27\frac{5}{8}$ |
| 54 | 26 | 15 | 4 | $5\frac{3}{4}$ | $31\frac{1}{2}$ | $36\frac{1}{4}$ | $7\frac{1}{2}$ | $26\frac{1}{2}$ | 28 |
| 60 | 28 | 16 | $4\frac{1}{4}$ | $6\frac{1}{4}$ | $34\frac{1}{2}$ | $38\frac{3}{4}$ | 8 | 29 | $30\frac{3}{4}$ |
| 60 | 30 | 17 | $4\frac{1}{2}$ | $6\frac{1}{2}$ | $35\frac{1}{4}$ | $41\frac{3}{4}$ | $8\frac{1}{2}$ | 30 | $31\frac{3}{4}$ |

All Dimensions are given in Inches.




Figs. 841, 842.—Wrist Plate for Corliss Gear.

TABLE 79.—**Dimensions of Wrist Plate for Corliss Valve Gear** (Figs. 841, 842).

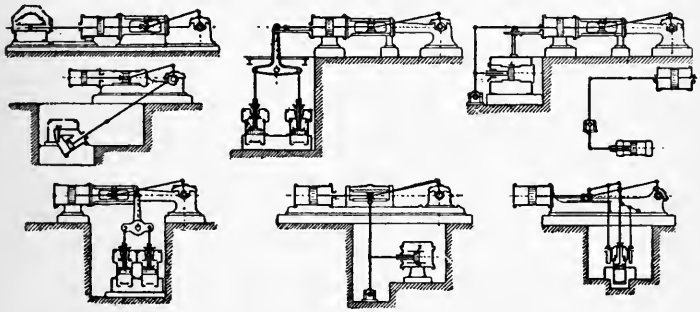
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 24 | $25\frac{1}{2}$ | $4\frac{7}{8}$ | $4\frac{1}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{8}$ | $1\frac{5}{8}$ | $2\frac{1}{2}$ | $5\frac{1}{4}$ | $\frac{3}{4}$ | $6\frac{3}{4}$ | 1 | $19\frac{1}{2}$ | $2\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{5}{16}$ |
| 54 | 26 | $27\frac{5}{16}$ | $5\frac{5}{8}$ | $4\frac{1}{2}$ | $3\frac{3}{4}$ | $1\frac{1}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{4}$ | $5\frac{1}{2}$ | $\frac{7}{8}$ | 7 | $1\frac{1}{8}$ | $20\frac{1}{2}$ | $2\frac{1}{2}$ | 2 | $1\frac{5}{16}$ |
| 60 | 28 | $28\frac{7}{8}$ | $5\frac{5}{8}$ | $4\frac{3}{4}$ | 4 | $1\frac{1}{4}$ | $1\frac{7}{8}$ | $2\frac{7}{8}$ | $5\frac{3}{4}$ | $\frac{7}{8}$ | 7 | $1\frac{1}{8}$ | $21\frac{1}{2}$ | $2\frac{5}{8}$ | $2\frac{1}{4}$ | $1\frac{3}{8}$ |
| 60 | 30 | $30\frac{1}{2}$ | 6 | $4\frac{3}{4}$ | $4\frac{1}{4}$ | $1\frac{3}{5}$ | 2 | 3 | 6 | $\frac{7}{8}$ | 7 | $1\frac{1}{8}$ | $23\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $1\frac{3}{4}$ |

All Dimensions are given in Inches.

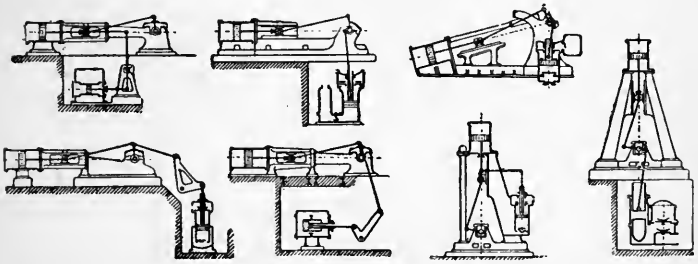
## SECTION V.

### CONDENSERS, AIR-PUMPS, AND FEED-PUMPS.

Condensers are divided into two principal classes: (*a*) *Injection Condensers*, where the condensing water acts in direct contact with the steam, and therefore mixes with the water from the condensed



Figs. 843—849.



Figs. 850 - 856.

steam; (*b*) *Surface Condensers*, where the condensing water acts on one side of a thin wall of metal, the steam being in contact with the other, and thus the water from the condensed steam is kept separate from the condensing water; these are the two varieties most in use.

A few special methods of condensing steam are occasionally used; of these some may be said to belong to the class (*a*), others to the class (*b*).

The earliest examples of condensers and air-pumps were vertical and single-acting, and were generally applied to beam engines. When horizontal engines came into fashion, the air-pumps were often vertical, worked by means of a bell-crank lever; but owing to the number of parts required to drive a vertical air-pump from a horizontal engine, the simpler method of putting the air-pump surrounded by the condenser horizontal, and in the same line as the piston-rod, and driving direct from the tail rod, has come into use to a large extent.

An objection to horizontal air-pumps driven in this way, has often been urged against their use, namely, that with high piston-speed engines, the speed of air-pump bucket, necessarily the same, is too high for efficiency. By good proportions this objection can be removed, and even speeds of 800 feet per minute have been used with good results, especially with plunger air-pumps like that shown in fig. 876, taken from the Allen engine made by Whitworth & Co.

Figs. 843 to 856 show in diagram several methods of driving air-pumps from both horizontal and vertical engines.

### (a.) Injector Condensers with Air-Pumps.

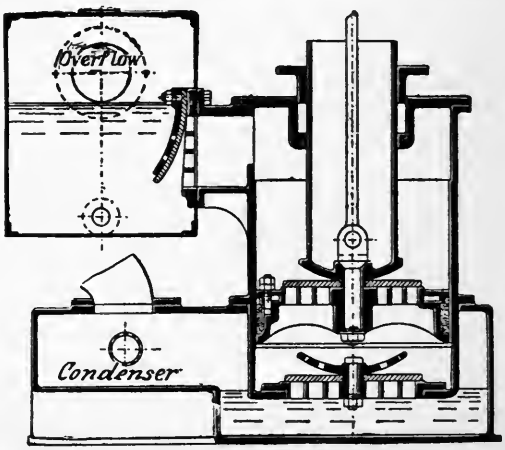
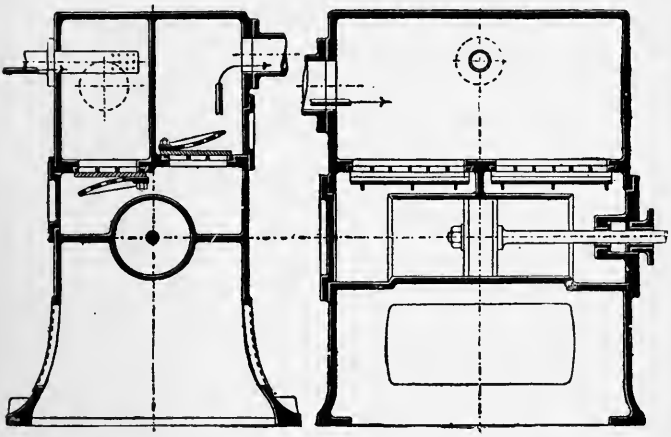
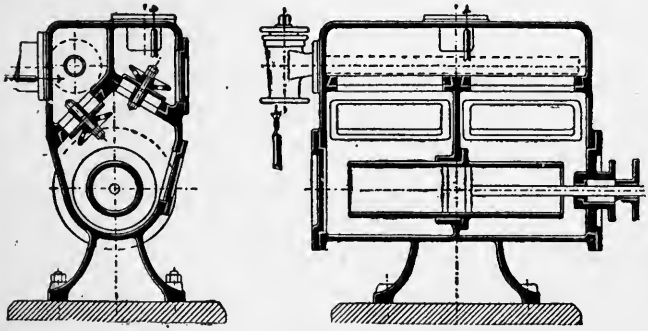


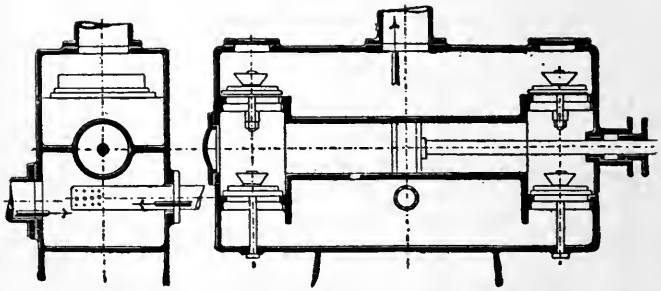

Fig. 857.—Vertical Bucket and Plunger Air-Pump of ordinary type.



Figs. 858, 859.—Horizontal Air Pump and Condenser with Rectangular Valves.

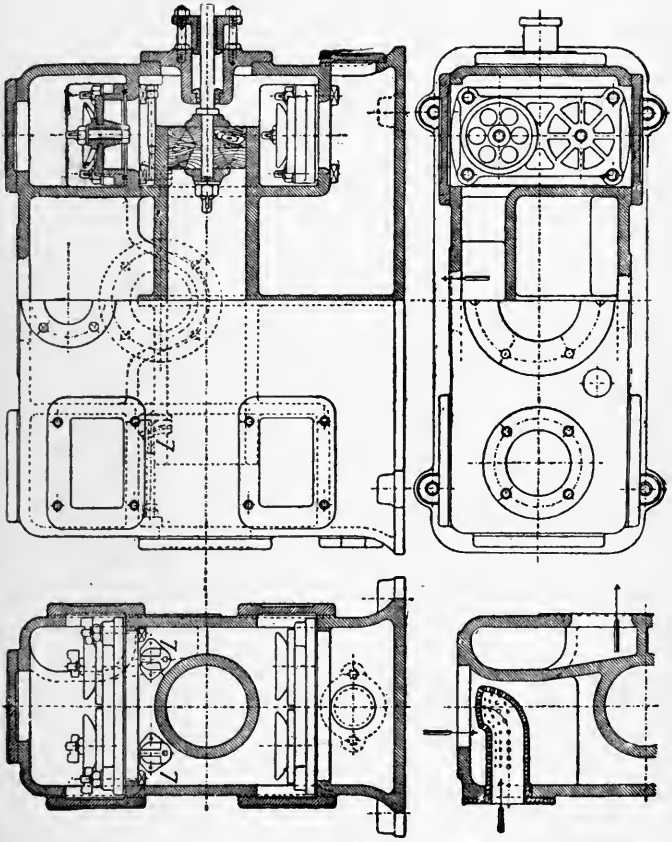


Figs. 860, 861.—Horizontal Air Pump and Condenser with Rectangular Valves, made by the Prince Rudolf Iron Works, Dülmen.

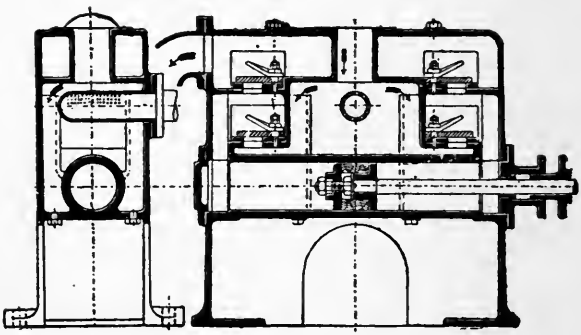


Figs. 862, 863.—Horizontal Air Pump and Condenser, with Rectangular Valves and Injection Nozzle, and Exhaust Inlet below the Barrel.

Horn's patent air pump and condenser, made by G. Brinkman & Co. of Witten, is shown in section, figs. 864—867 and 870—872 ; the air pump piston or bucket is shown at the right hand end of the barrel and is just starting back to the left, at this moment the space between the suction and delivery valves and piston is full of water, as the piston continues to move to the left the water level sinks, (whilst the delivery valve remains closed by the external atmospheric pressure,) and maintains a vacuum in the space between the surface of the water and delivery valve ; as the water level sinks it allows the small air valves, L L, to open, and any air in the condensing chamber passes through into the space left by the movement of the piston, without having to pass through the suction valve below, whilst the water from the condensing chamber passes through the suction valve. The water and air are thus kept separate, and also the air is drawn out of the condensing chamber through the small valves, L L, at the beginning of the piston stroke, and not, as is usually the case with horizontal air pumps, at the end of the stroke through the suction valves, which are necessarily placed low down. This construction should get over the difficulty which often occurs of getting rid of the air quietly, and should secure the prompt closing of the delivery valves.

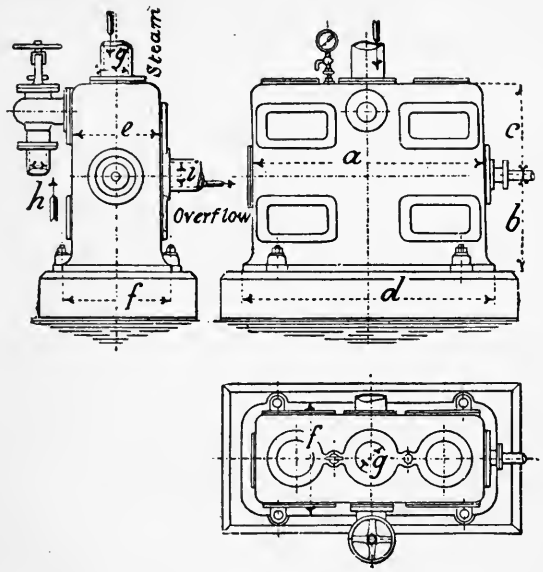


Figs. 864—867.



Figs. 868, 869.—Ed. König's Patent Air Pump and Condenser, with Suction and Delivery Valves above Barrel.

In Ed. König's air pump made by the Chemnitz Steam Engine and Spinning Machine Works, both the suction and delivery valves are above the barrel, figs. 868, 869.

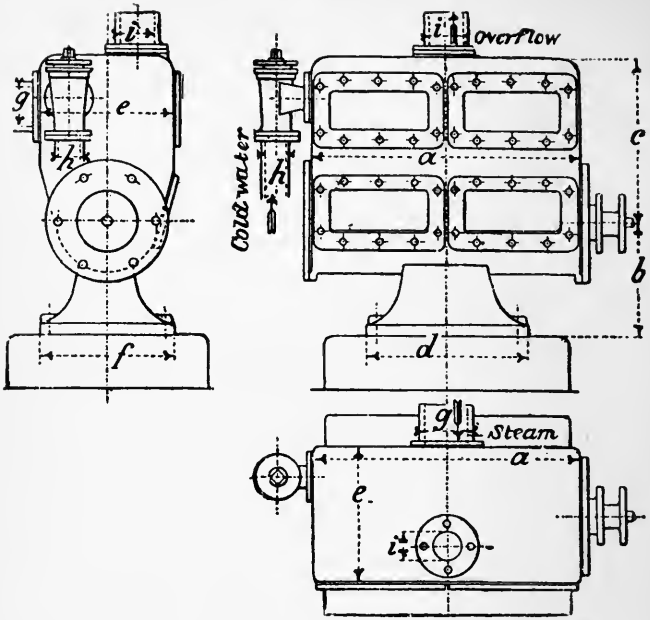



Figs. 870—872.—Outside Views of Horn's Patent Air Pump and Condenser.

TABLE 80.—**Dimensions of Horn's Patent Air Pump and Condenser** (Figs. 864—867 and 870—872).

| Engine. | | Air Pump and Condenser. | | | | | | | | Pipes. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | H | D | *a* | *b* | *c* | *d* | *e* | *f* | Exhaust. *g* | Injection. *h* | Overflow. *i* |
| 19⅝ | 11¾ | 19⅝ | 5 | 33½ | 15¾ | 15¾ | 37½ | 13¾ | 17⅝ | 3½ | 2⅜ | 4 |
| 23⅝ | 13¾ | 23⅝ | 6¼ | 39½ | 16½ | 17 | 43½ | 15 | 19 | 4⅜ | 3 | 4¾ |
| 27½ | 15¾ | 27½ | 7 | 47¼ | 17⅝ | 17⅝ | 51¼ | 16 | 20 | 5 | 4 | 5½ |
| 31½ | 17⅝ | 31½ | 7¾ | 49¼ | 19⅝ | 19⅝ | 54¼ | 19⅝ | 23⅝ | 5½ | 4¾ | 6¼ |
| 35½ | 19⅝ | 35½ | 8¾ | 65 | 19⅝ | 20½ | 69¼ | 22½ | 27½ | 6¼ | 5½ | 7 |
| 39½ | 21⅝ | 3°½ | 9¾ | 65 | 27½ | 25½ | 71 | 27½ | 35½ | 7 | 6¼ | 8 |

All Dimensions are given in Inches.

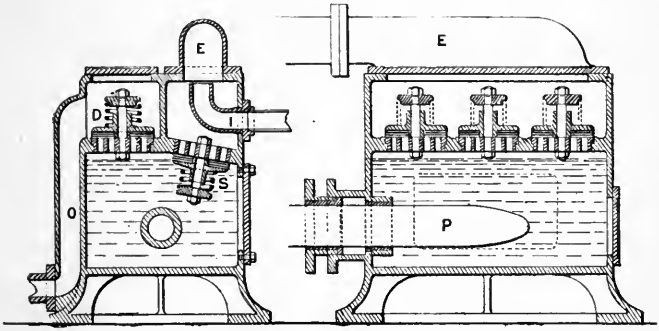



Figs. 873—875.—Outside Views of the Dülmen Air Pump and Condenser.

TABLE 81.—**Dimensions of Air Pump and Condenser** (Figs. 873—875 and 860, 861).

| Engine. | | Air Pump and Condenser. | | | | | | | | Pipes. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | H | D | *a* | *b* | *c* | *d* | *e* | *f* | Exhaust. *g* | Injection. *h* | Overflow. *i* |
| 19⅝ | 11¾ | 19⅝ | 4⅜ | 33½ | 13¾ | 19⅝ | 23⅝ | 16½ | 15¾ | 3½ | 2⅜ | 2¾ |
| 23⅝ | 13¾ | 23⅝ | 5 | 37⅜ | 15¾ | 20⅝ | 27½ | 16½ | 17⅝ | 4 | 2⅜ | 3¼ |
| 27½ | 15¾ | 27½ | 5½ | 43⅜ | 19⅝ | 23⅝ | 33½ | 19¾ | 21⅝ | 5 | 2⅜ | 3½ |
| 31½ | 17⅝ | 31½ | 6¼ | 49 | 23⅝ | 24⅝ | 39⅜ | 19¾ | 27½ | 6 | 3¼ | 4 |
| 35½ | 19⅝ | 35½ | 7 | 55 | 23⅝ | 26½ | 43⅜ | 19¾ | 31½ | 6 | 3½ | 5 |
| 39½ | 21⅝ | 39½ | 8 | 59 | 27½ | 28½ | 47¼ | 21⅝ | 31½ | 7 | 4 | 5 |

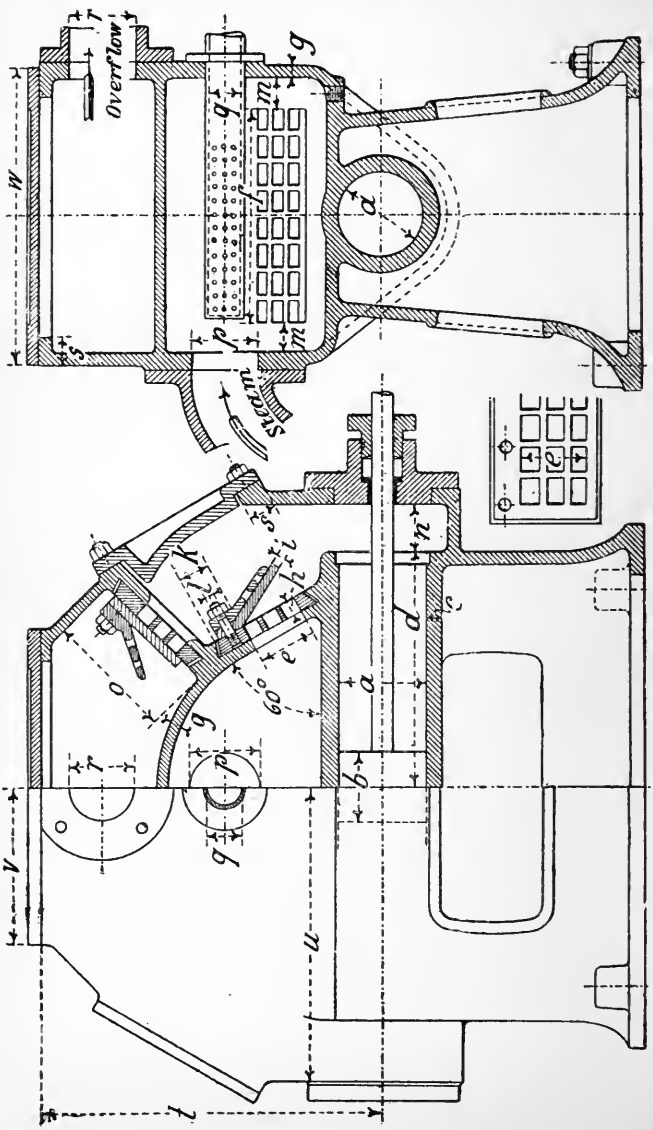
All Dimensions are given in Inches.




Figs. 876, 877.—Plunger Air Pump and Condenser from the Allen Engine.

E, exhaust pipe.
P, plunger.
O, overflow pipe.
Diameter of engine piston, 12″.
Stroke, 24″.
Revs. per minute, 200.
Diameter of air pump piston, 5″.

A full account of this engine will be found in Proceedings of Inst. Mech. Engineers for 1868.




Figs. 879—880.

TABLE 82.—**Dimensions of Air Pump and Condenser** (Figs. 878—880).

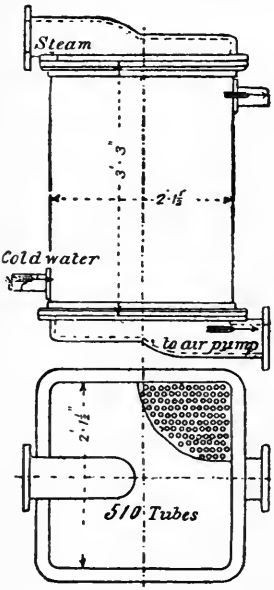
| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* | *t* | *u* | *v* | *w* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 24 | 12 | $4\frac{3}{4}$ | 4 | $\frac{7}{8}$ | $12\frac{5}{8}$ | $3\frac{1}{4}$ | $11\frac{5}{8}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{1}{2}$ | $2\frac{5}{8}$ | $6\frac{3}{4}$ | $3\frac{5}{8}$ | $2\frac{3}{8}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | 18 | 16 | $8\frac{3}{8}$ | 16 |
| 28 | 14 | $5\frac{5}{8}$ | $4\frac{3}{8}$ | $\frac{7}{8}$ | $14\frac{3}{4}$ | $3\frac{5}{8}$ | $12\frac{3}{4}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{3}{4}$ | $\frac{5}{8}$ | $1\frac{3}{4}$ | 3 | 8 | $4\frac{3}{8}$ | 3 | $3\frac{3}{4}$ | $1\frac{1}{2}$ | $20\frac{3}{4}$ | $18\frac{5}{8}$ | $9\frac{3}{4}$ | $17\frac{5}{8}$ |
| 32 | 16 | $6\frac{3}{8}$ | $4\frac{3}{4}$ | $\frac{7}{8}$ | 17 | 4 | 14 | $\frac{5}{8}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | 2 | $\frac{3}{4}$ | $2\frac{1}{8}$ | $3\frac{3}{8}$ | 9 | 5 | $3\frac{5}{8}$ | $4\frac{3}{8}$ | $1\frac{1}{2}$ | $22\frac{3}{4}$ | $21\frac{1}{4}$ | $11\frac{1}{4}$ | $19\frac{5}{8}$ |
| 36 | 18 | $6\frac{3}{4}$ | $5\frac{1}{4}$ | 1 | $19\frac{3}{8}$ | $4\frac{3}{4}$ | $15\frac{1}{4}$ | $\frac{3}{4}$ | $\frac{7}{8}$ | $\frac{5}{8}$ | 2 | $\frac{3}{4}$ | $2\frac{1}{2}$ | 4 | 10 | $5\frac{5}{8}$ | $4\frac{1}{4}$ | 5 | $1\frac{1}{2}$ | $25\frac{1}{4}$ | $23\frac{3}{4}$ | $12\frac{3}{4}$ | $21\frac{5}{8}$ |
| 40 | 20 | 8 | $5\frac{5}{8}$ | 1 | $21\frac{5}{8}$ | $5\frac{5}{8}$ | $16\frac{3}{4}$ | $\frac{3}{4}$ | 1 | $\frac{5}{8}$ | 2 | $\frac{3}{4}$ | $2\frac{3}{4}$ | $4\frac{3}{8}$ | 11 | $6\frac{3}{4}$ | $4\frac{3}{4}$ | $5\frac{5}{8}$ | $1\frac{3}{4}$ | $27\frac{5}{8}$ | $26\frac{3}{4}$ | $14\frac{3}{8}$ | 24 |
| 44 | 22 | $8\frac{3}{4}$ | 6 | 1 | 24 | $6\frac{3}{8}$ | $18\frac{3}{8}$ | $\frac{3}{4}$ | 1 | $\frac{5}{8}$ | 2 | $\frac{3}{4}$ | 3 | $4\frac{3}{4}$ | 12 | $7\frac{1}{4}$ | $5\frac{1}{4}$ | 6 | $1\frac{3}{4}$ | 30 | $29\frac{5}{8}$ | 16 | 26 |

All Dimensions are given in Inches.

The quantity of condensing water required depends in some measure upon the temperature, but a rule which will serve as a basis upon which to judge of the amount required is from 20 to 30 times the amount of feed water used; an actual example taken by measuring the overflow water as it left the condenser gave from 61 to 80 gallons per indicated HP per hour; the temperature of the injection water was 56°, and that of the overflow 100°; the engine had a 12″ piston and 15″ stroke, the boiler pressure being 55 lbs., and at the time when the water was measured indicated from 20 to 24 HP; the air pump was a vertical plunger pump.

### (b.) Surface Condensers.

Surface condensers are now almost exclusively used in marine work, and enable the boilers to be worked at much higher pressures




Figs. 881, 882.

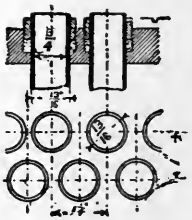
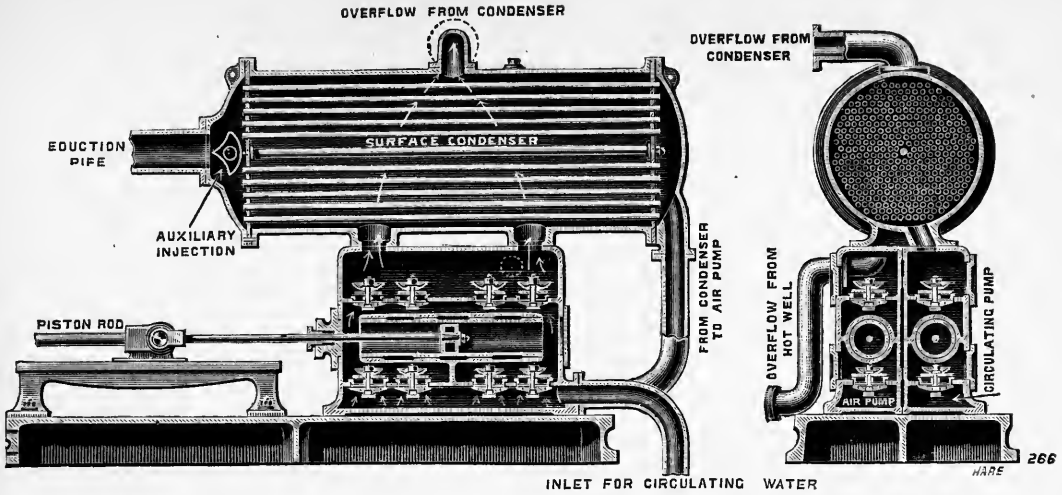


Fig. 883.

on account of the purity of the feed water, only a small amount of auxiliary feed being used direct from the sea; they are also increasing in use on land, especially where water is plentiful but bad; their




Figs. 884, 885.—Horizontal Surface Condenser and Air Pump, by Messrs. Ruston, Proctor & Co., Lincoln.

first cost is much greater than an ordinary jet condenser, but there is much to be said as to their suitability for special positions, such as by the side of brackish rivers, or rivers where the water has a bad action on boiler plates. An outside view of one form is shown in figs. 881, 882, and fig. 883 shows one method of fixing the tubes. The tubes are usually of solid drawn brass of $\frac{5}{8}''$ or $\frac{3}{4}''$ or $\frac{13}{16}''$ diameter, the tube plates of brass or copper. $\frac{5}{8}''$ tubes run $10\frac{3}{4}''$ to the lb., $\frac{3}{4}''$ tubes, $9\frac{1}{2}''$ to the lb., the thickness being 18 B W G.

The method shown in fig. 883, of fixing the tubes by small screwed glands and packing allows of free expansion and contraction, and also admits of a tube being drawn for examination. In marine surface condensers the cooling surface is about 3 square feet per indicated HP. A surface condenser combined with air and circulating pumps, by Messrs. Ruston & Proctor of Lincoln, is shown in figs. 884, 885, arranged for placing behind the cylinder of a horizontal engine, on an extension of the bed plate ; in this example the exhaust steam is passed through the tubes, the circulating water being pumped through the chamber containing them, and thus coming in contact with the outside of the tubes ; many surface condensers are made so that the circulating water is pumped through the tubes, the exhaust steam passing through the chamber, and coming into contact with the outside of the tubes.

The quantity of circulating water required varies from 55 to 90 gallons per indicated HP per hour.

In places where the supply of water for condensing is limited, various devices have been used for cooling the condensing water, so that it may be used over again with the addition of a small amount of make up. Shallow cooling ponds have been and are in use successfully in many places, but these take up large and valuable ground space, and their use is therefore limited. Other devices are now coming largely into use, the most important of these being the Cooling Tower, in which the condensing water is raised to the top of a high tower and allowed to trickle down over wooden gratings so as to distribute the water over a large surface, exposed to the air, and in most cases to the draught from a fan. An ingenious device by Theisen,* of the Engine Works, Grevenbroich, is shown in fig. 886 ; here the water is cooled by a series of metal discs dipping partly in water and kept slowly revolving, a fan draws dry air through the spaces between the discs, and cools them by evaporation.

---

* A full account of this arrangement appeared in Dingler's Journal, Vol. 267, Part 13, page 586.

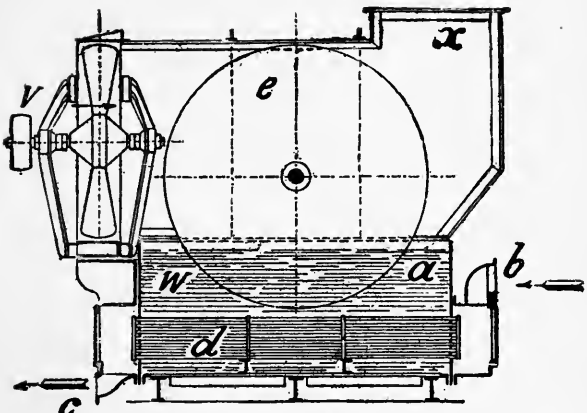



Fig. 886.—Theisen's Cooling Apparatus for Condensing Water.

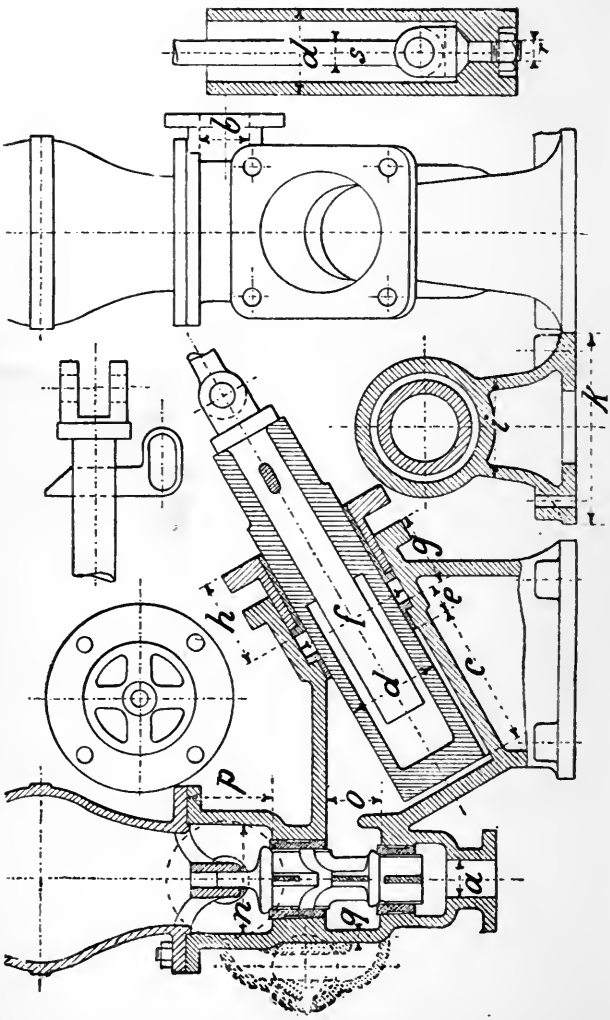
The cold water reservoir *a*, with surface condenser tubes immersed : *b*, inlet for exhaust steam ; *e*, a series of metal discs partially immersed in the condensing water, as they revolve a current of air is forced over them by the fan, V, fig. 886 ; *x*, outlet for vapour and air from fan.

Other special varieties of condenser are known as Ejector condensers, and have no air pump or moving parts ; they are almost the same in construction as the Giffards Injector, and are kept at work by a stream of cold water from a tank overhead ; their action is continuous, and they keep a fair vacuum.

The economy obtained by using a condenser varies too much in practice to allow of a definite figure being given, but it may be taken as from 15 per cent. upwards.

### (c.) Feed Pumps.

Feed pumps are made in endless variety, according to their position on the engine or boiler ; formerly all engines had a feed pump attached to some part of the frame or bed, now the tendency is to have a separate feed system, worked by its own donkey engine, placed close to the boilers. Locomotives depend upon some form of injector, and very often on large portable or under-type engines an auxiliary feed by injector or donkey pump is provided. When a




Figs. 887—891.

TABLE 83.—**Dimensions of Feed Pump** (Figs. 887—891).

| Engine. | | Feed-pump. | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | D | *d* | H | *a* | *b* | *c* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *s* |
| 12 | 6 | $1\frac{1}{4}$ | $1\frac{3}{4}$ | $\frac{3}{4}$ | $\frac{3}{4}$ | $1\frac{3}{4}$ | 1 | $2\frac{1}{4}$ | 2 | $2\frac{3}{8}$ | $1\frac{1}{4}$ | $5\frac{1}{4}$ | 1 | $1\frac{1}{4}$ | 2 | $1\frac{5}{8}$ | $2\frac{3}{8}$ | $\frac{1}{2}$ | — | — |
| 16 | 8 | $1\frac{5}{8}$ | 2 | $1\frac{1}{4}$ | 1 | $1\frac{7}{8}$ | $1\frac{1}{4}$ | $2\frac{3}{4}$ | $2\frac{5}{8}$ | $2\frac{3}{4}$ | $1\frac{5}{8}$ | $5\frac{5}{8}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $2\frac{3}{8}$ | 2 | $2\frac{3}{4}$ | $\frac{1}{2}$ | — | — |
| 20 | 10 | 2 | $2\frac{5}{8}$ | $1\frac{3}{8}$ | $1\frac{1}{4}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | $2\frac{3}{8}$ | $3\frac{1}{4}$ | $3\frac{3}{8}$ | 2 | $6\frac{3}{8}$ | $1\frac{1}{2}$ | 2 | $2\frac{3}{4}$ | 2 | $3\frac{1}{4}$ | $\frac{1}{2}$ | — | — |
| 24 | 12 | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $1\frac{1}{2}$ | $1\frac{3}{8}$ | $3\frac{1}{8}$ | $1\frac{3}{8}$ | $4\frac{1}{4}$ | $3\frac{3}{4}$ | 4 | $2\frac{3}{4}$ | $7\frac{1}{4}$ | 2 | $2\frac{3}{8}$ | $3\frac{3}{8}$ | $2\frac{3}{4}$ | $3\frac{5}{8}$ | $\frac{1}{2}$ | 1 | $1\frac{1}{4}$ |
| 28 | 14 | $3\frac{1}{4}$ | $3\frac{5}{8}$ | $1\frac{3}{4}$ | $1\frac{3}{4}$ | $3\frac{5}{8}$ | $1\frac{1}{2}$ | $4\frac{3}{4}$ | $4\frac{3}{8}$ | $4\frac{3}{8}$ | $3\frac{1}{4}$ | 8 | $2\frac{1}{4}$ | $2\frac{5}{8}$ | 4 | 3 | 4 | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{3}{8}$ |
| 32 | 16 | $3\frac{5}{8}$ | 4 | 2 | 2 | 4 | $1\frac{3}{4}$ | $5\frac{1}{4}$ | 5 | $4\frac{3}{4}$ | $3\frac{5}{8}$ | $8\frac{3}{8}$ | $2\frac{3}{8}$ | $2\frac{7}{8}$ | $4\frac{3}{8}$ | $3\frac{1}{4}$ | $4\frac{3}{8}$ | $\frac{1}{2}$ | $1\frac{1}{4}$ | $1\frac{5}{8}$ |
| 36 | 18 | 4 | $4\frac{3}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | $4\frac{3}{8}$ | 2 | $5\frac{5}{8}$ | $5\frac{5}{8}$ | $5\frac{1}{4}$ | 4 | $9\frac{1}{4}$ | $2\frac{3}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{4}$ | $3\frac{3}{8}$ | $4\frac{3}{4}$ | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ |
| 40 | 20 | $4\frac{3}{8}$ | 5 | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $4\frac{3}{4}$ | $2\frac{3}{8}$ | 6 | 6 | $5\frac{3}{8}$ | $4\frac{5}{8}$ | 10 | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $5\frac{3}{8}$ | $3\frac{5}{8}$ | $5\frac{1}{4}$ | $\frac{1}{2}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ |
| 44 | 22 | $4\frac{3}{4}$ | $5\frac{5}{8}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $5\frac{3}{8}$ | $2\frac{3}{4}$ | $6\frac{3}{8}$ | $6\frac{3}{8}$ | $5\frac{5}{8}$ | $5\frac{1}{4}$ | $10\frac{3}{4}$ | $3\frac{5}{8}$ | $4\frac{1}{4}$ | 6 | 4 | $5\frac{5}{8}$ | $\frac{5}{8}$ | $1\frac{3}{8}$ | 2 |

range of boilers is fed from one pump, there must be a feed escape valve, placed so as to command the whole feed system, and loaded so as to blow off a little above the boiler pressure, and this valve should be in a conspicuous position ; if any obstruction occur this valve will blow off and show that there is something resisting the flow of the water.

An ordinary feed pump for bolting down to the engine foundation, and worked by an eccentric, is shown in fig. 887. A method of disengaging the plunger, is shown in upper fig., this method is often

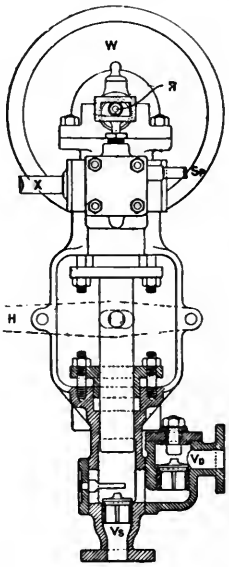



Fig. 892.

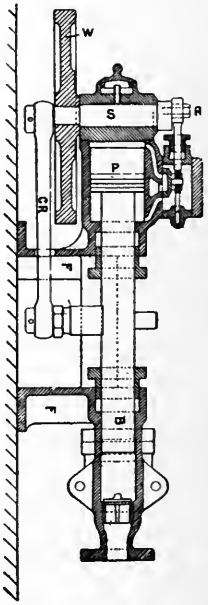



Fig. 893.

used in slow moving pumps when required to do intermittent work, but is not often applied to boiler feed pumps.

Figs. 892—893, show a simple boiler feeding donkey pump.

F F, the frame by which the pump is bolted to the wall ; W, the fly wheel ; S, the crank shaft ; R, a small crank pin for working the slide valve ; P, the steam piston ; B, the pump plunger ; V *d*, the delivery valve ; V *s*, the suction valve ; H, a hand lever for working the pump by hand when required.

NOTE. See also page 446A.

### (d.) Feed-Water Heaters.

Feed-water heaters are extensively used, and effect great economy in fuel. They may be considered as a reversed surface condenser, the exhaust steam being used to warm the water as it passes from the

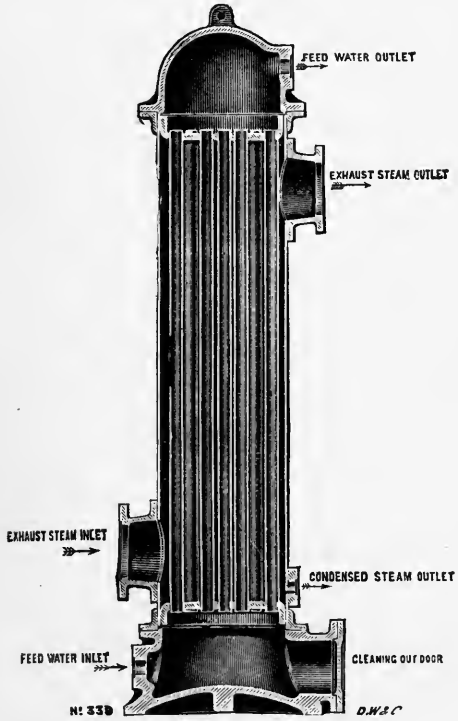
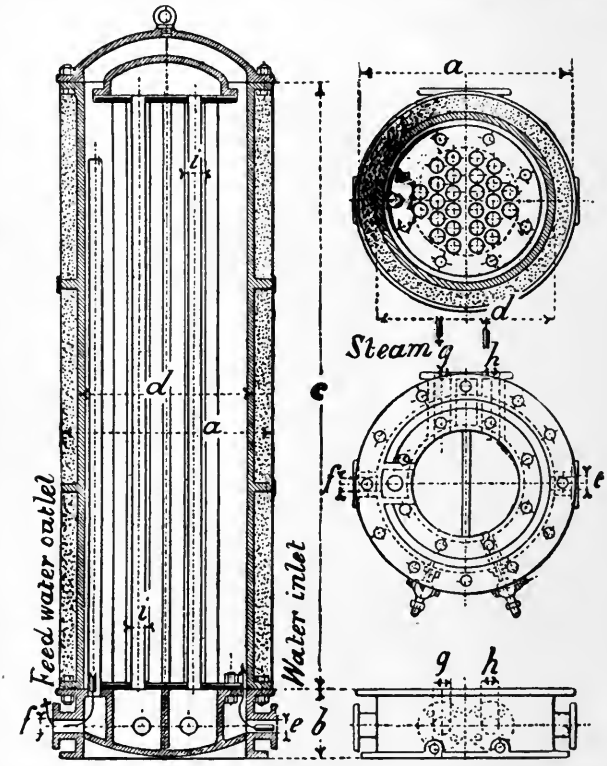



Fig. 894.—Feed-Water Heater, by Messrs. Marshall Sons & Co. Ltd., Gainsboro.

pump to the boiler, two examples are shown in figs. 894—895. Feed-water heaters of this type are sometimes placed horizontally. If pure water could be used, the heaters would work efficient y for long periods, but as water always contains mineral matters which are partially precipitated when the water is warmed, the heater tubes become coated with scale, and have to be cleaned. Occasionally, the feed water seems to select certain tubes for its flow, and not infre-

quently, if the heaters have been neglected, only some of the tubes are deeply scaled,* the rest being comparatively free; baffle plates, to ensure good distribution of the water, would possibly prevent this




Figs. 895—898.—Feed-heater, by the Prince Rudolf Iron Works, Dülmen.

selection. From the scaling it is obvious that feed-water heaters are to a certain extent feed-water purifiers, and if of ample size, must act beneficially in this direction. In some feed-heaters, the tubes are re-

* An instance of this occurred in practice where a vertical heater of the above type, with about 65 tubes, had been in use for a long time without cleaning, upwards of 50 of the tubes were totally blocked up, and the remainder comparatively clear.

placed by an arched branch of exhaust pipe, or this arched branch may be made up of a number of tubes through which the exhaust passes, and the feed water is pumped through the case containing the tubes. These heaters are now very much used, and have proved to be quite satisfactory.

Other types of heaters depend on a small jet of water from the feed pump used as an injector to carry a part of the exhaust steam into a tank, and thus heating the water ; this arrangement is used on agricultural engines, but it has the disadvantage of introducing grease from the exhaust into the feed water.

The maximum speed of the feed water in any part of the feed system should not exceed from 120 to 160 feet per minute.

TABLE 84.—**Dimensions of Feed-Water Heater** (Figs. 895—898).

| Nominal H.P. | Heating-surface in sq. ft. | *a* | *b* | *c* | *d* | Feed-water. | | Steam. | | Tubes | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Inlet | Outlet | Inlet | Outlet | No. | *i* |
| 10 | 7·53 | $17\frac{3}{4}$ | $11\frac{3}{4}$ | 42 | $13\frac{3}{4}$ | $1\frac{1}{4}$ | $1\frac{1}{4}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | 4 | 2 |
| 15 | 10·76 | $17\frac{3}{4}$ | $11\frac{3}{4}$ | 61 | $13\frac{3}{4}$ | $1\frac{5}{8}$ | $1\frac{5}{8}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | 4 | 2 |
| 25 | 16·14 | $19\frac{3}{4}$ | $13\frac{3}{4}$ | 59 | $15\frac{3}{4}$ | 2 | 2 | $3\frac{1}{8}$ | $3\frac{1}{8}$ | 6 | 2 |
| 40 | 26·90 | 26 | $13\frac{3}{4}$ | 67 | $21\frac{5}{8}$ | 2 | 2 | $3\frac{1}{2}$ | $3\frac{1}{2}$ | 10 | 2 |
| 60 | 37·66 | 28 | $13\frac{3}{4}$ | 67 | $23\frac{5}{8}$ | 2 | 2 | 4 | 4 | 14 | 2 |
| 80 | 64·56 | 28 | $13\frac{3}{4}$ | $86\frac{1}{2}$ | $23\frac{5}{8}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | 5 | 5 | 18 | 2 |
| 100 | 91·46 | $34\frac{1}{4}$ | $15\frac{3}{4}$ | $74\frac{1}{2}$ | $29\frac{1}{2}$ | $2\frac{3}{8}$ | $2\frac{3}{8}$ | 6 | 6 | 30 | 2 |
| 125 | 107·6 | $34\frac{1}{4}$ | $15\frac{3}{4}$ | $86\frac{1}{2}$ | $29\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | 6 | 6 | 30 | 2 |
| 150 | 177·5 | $44\frac{1}{2}$ | $17\frac{3}{4}$ | 71 | $39\frac{3}{8}$ | $3\frac{1}{8}$ | $3\frac{1}{8}$ | 7 | 7 | 6 | 2 |

All Dimensions are given in Inches except the Heating-surface.

## SECTION VI.

### EXAMPLES OF VARIOUS TYPES OF HORIZONTAL AND VERTICAL ENGINES FROM ACTUAL PRACTICE.

**With Tables of Dimensions, Weights, &c.**

**Horizontal Engines of the more usual Types.**

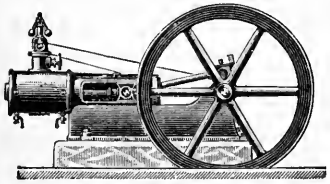


Fig. 899.

Engine with forked or **Y** frame, bent or slotted out crank shaft, arranged to carry the fly-wheel outside the bearings on either side of the engine, frequently known as "self-contained" horizontal engines. These engines are usually made with cylinders from 5 to 12 inches diameter, the stroke being from $1\frac{1}{4}$ to $1\frac{1}{2}$ times the diameter.

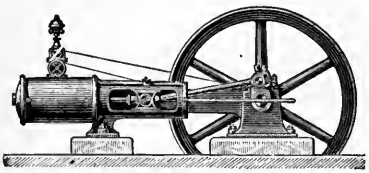


Fig. 900.

Girder or "Corliss" Frame Engines, with cylinder bolted on to end of, and overhanging the girder. Frame unsupported except by a foot at each end. Crosshead guides cast in the frame for small and medium-sized engines, and either bored or with planed flat surfaces.

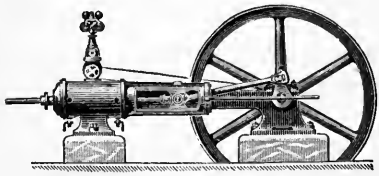


Fig. 901.

Girder type of engine supported by feet on cylinder, and at end of frame under crank shaft bearings. Piston rod extended and guided through back cylinder cover. Crosshead guides cast in one with frame in small and medium-sized engines.

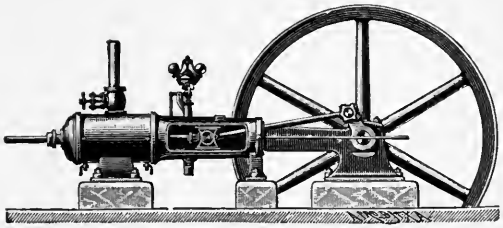


Fig. 902

Girder type of engine with extra supporting foot under centre of frame.

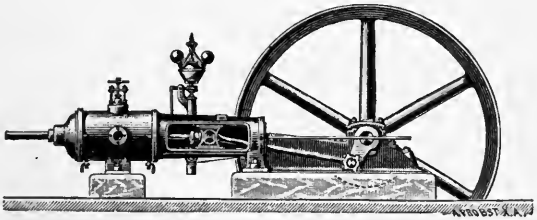


Fig. 903.

Semi-Girder type of engine, with half the length of frame bolted down to foundation, and with support under cylinder.

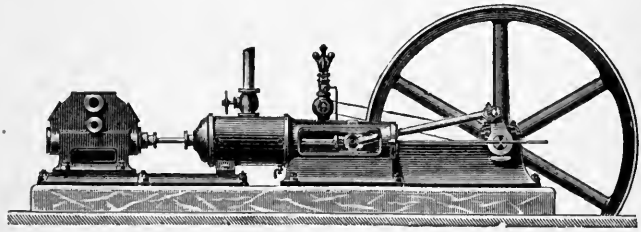


Fig. 904.

Condensing engine, with air-pump at back of cylinder and worked by tail rod.

TABLE 85.—**Dimensions of Horizontal Steam Engines.**

| Stroke . . . H | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 |
|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder . D | 8 9 | 10 11 | 12 13 | 14 15 | 16 17 | 18 19 | 20 21 | 22 23 | 24 25 |
| Ratio . . H : D | 2 1·78 | 2 1·82 | 2 1·85 | 2 1·87 | 2 1·88 | 2 1·89 | 2 1·90 | 2 1·91 | 2 1·92 |
| Revolutions per minute $n$ | 110 | 100 | 90 | 85 | 80 | 78 | 75 | 72 | 70 |
| Piston speed in feet per minute . . . . | 283 | 334 | 360 | 396 | 426 | 468 | 500 | 528 | 560 |
| Diameter of fly-wheel . | 66 | 84 | 96 | 120 | 138 | 156 | 180 | 192 | 216 |

All Dimensions are given in Inches.

TABLE 86.—**Dimensions of Horizontal Corliss Engines.**

| Stroke . . H | 30 | | 36 | | 42 | | | 48 | | | 54 | | | 60 | | 66 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder . . D | 10 | 12 | 12 | 14 | 14 | 16 | 18 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 |
| Ratio . . H : D | 3 | 2·67 | 3 | 2·57 | 3 | 2·62 | 2·33 | 3 | 2·66 | 2·40 | 2·45 | 2·25 | 2·07 | 2·15 | 2·00 | 2·06 | 1·97 |
| Revolutions per minute . $n$ | 80 | 75 | | 72 | | 70 | | 68 | | | 65 | | | 60 | | 55 | |
| Piston speed in feet per minute | 400 | 375 | 465 | 432 | 505 | 490 | 490 | 544 | | | 585 | | | 600 | | 605 | |
| Diameter of fly-wheel . . | 108 | 120 | 120 | 132 | 144 | 156 | 168 | 168 | 180 | 192 | 204 | 216 | 240 | 264 | 288 | 312 | 336 |

All Dimensions are given in Inches.

## TABLE 87.—Dimensions of Vertical Steam Engines.

| Stroke . . H | 6 | | 8 | | 10 | | 12 | | 16 | | 20 | | 24 | | 30 | | 36 | | 42 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder . . D | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 28 | 30 | 34 | 38 | 42 | 46 |
| Ratio . H : D | 1·5 | 1·2 | 1·33 | 1·14 | 1·25 | 1·11 | 1·20 | 1·00 | 1·14 | 1·00 | 1·11 | 1·00 | 1·09 | 1·00 | 1·07 | 1·00 | 1·06 | ·95 | 1·00 | ·91 |
| Revolutions per minute . . $n$ | 300 | | 280 | | 260 | | 245 | | 210 | | 180 | | 160 | | 130 | | 110 | | 100 | |
| Piston speed in feet per minute . . | 300 | | 374 | | 434 | | 490 | | 560 | | 600 | | 640 | | 650 | | 660 | | 700 | |
| Diameter of flywheel . . . | 42 | | 48 | | 54 | | 60 | | 72 | | 84 | | 96 | | 120 | | 144 | | 168 | |

All Dimensions are given in Inches.

TABLE 88.—**Dimensions of Compound Engines.**

| Stroke . . H | 20 | | 24 | | 28 | | 32 | | 36 | | 40 | | 44 | | 48 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of high pressure cylinder . . | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| Diameter of low pressure cylinder . . | 16 | 17½ | 19 | 20½ | 22 | 24 | 25 | 27 | 29 | 30 | 32 | 33 | 35 | 37 | 38 | 40 |
| Ratio of capacities . . | 2·56 | 2·53 | 2·51 | 2·49 | 2·46 | 2·56 | 2·44 | 2·52 | 2·60 | 2·49 | 2·56 | 2·46 | 2·46 | 2·58 | 2·51 | 2·56 |
| Revolutions per minute | 90 | | 80 | | 75 | | 70 | | 68 | | 65 | | 62 | | 60 | |
| Piston speed in feet per minute . . . | 300 | | 320 | | 350 | | 373 | | 408 | | 433 | | 455 | | 480 | |
| Diameter of fly-wheel . | 78 | | 96 | | 120 | | 138 | | 162 | | 180 | | 198 | | 216 | |

All Dimensions are given in Inches.

TABLE 89.—**Dimensions of Compound Corliss Engines.**

| Stroke . . . . . H | 30 | | 36 | | 42 | | | 48 | | | 54 | | | 60 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diam. of high-pressure cylinder | 10 | 12 | 12 | 14 | 14 | 16 | 18 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 |
| Diam. of low-pressure cylinder | 16 | 19 | 19 | 22 | 22 | 25 | 29 | 25 | 29 | 32 | 35 | 38 | 42 | 44 | 48 |
| Ratio of capacities . . . | 2·56 | 2·51 | 2·51 | 2·46 | 2·46 | 2·44 | 2·60 | 2·44 | 2·60 | 2·56 | 2·46 | 2·51 | 2·60 | 2·46 | 2·56 |
| Revolutions per minute . . | 80 | 75 | | 72 | | 70 | | 68 | | | 65 | | | 60 | |
| Piston speed in feet per minute | 400 | 375 | 465 | 432 | 505 | 490 | 490 | 544 | | | 585 | | | 600 | |
| Diameter of fly-wheel | 108 | 120 | | 132 | 144 | 156 | 168 | 180 | 192 | 204 | 216 | 240 | 264 | 288 | 312 |

All Dimensions are given in Inches.

## Leading Dimensions of Single Cylinder Horizontal Engines, with and without Condensers.

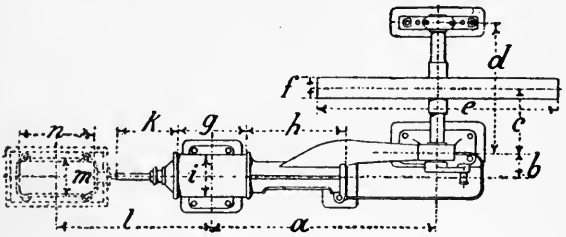


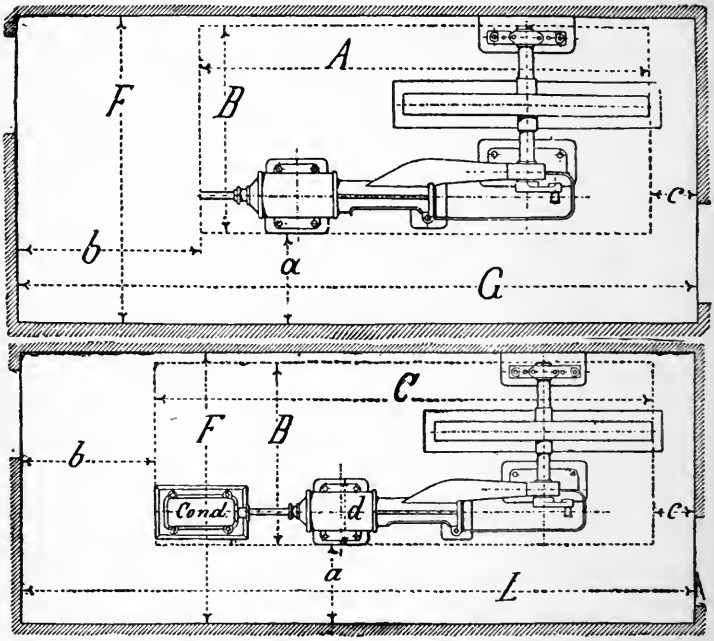

Fig 905.

TABLE 90.—**Overall Dimensions of Horizontal Engines** (Fig. 905).

| H | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 75 | 9 | 27¾ | 51 | 75 | 8 | 22 | 36½ | 15¾ | — | — | — | — |
| 20 | 90 | 10¾ | 29¾ | 57 | 93 | 10 | 26¾ | 42 | 18½ | 30½ | 71 | 17¾ | 33½ |
| 24 | 105 | 12½ | 31½ | 63 | 110 | 12 | 31½ | 48 | 21¼ | 36 | 77 | 19 | 39 |
| 28 | 122 | 14 | 34 | 69 | 130 | 14¾ | 36½ | 54½ | 23¾ | 40½ | 82 | 20 | 47 |
| 32 | 136 | 15½ | 35½ | 75 | 150 | 17 | 41 | 60 | 26 | 45 | 98 | 23¾ | 49 |
| 36 | 151 | 17 | 39½ | 83 | 165 | 20 | 45½ | 66 | 28¾ | 50 | 108 | 27½ | 65 |
| 40 | 168 | 18½ | 43½ | 90 | 185 | 21¾ | 50 | 73½ | 30¾ | 55½ | 118 | 36 | 65 |

All Dimensions are given in Inches.

**Floor Space required for Single Cylinder Horizontal Engines, with and without Condensers.**




Figs. 906, 907.

TABLE 91.—**Floor Space Dimensions for Horizontal Engines** (Figs. 906, 907).

| Without condenser, fig. 906. | | | | | | | | | With condenser fig. 907. | |
|---|---|---|---|---|---|---|---|---|---|---|
| H | A | B | *a* | *b* | *c* | *d* | F | G | C | L |
| 16 | 126 | 40 | 32 | 63 | 20 | 24 | 110 | 209 | — | — |
| 20 | 181 | 50 | 36 | 67 | 20 | 28 | 130 | 268 | 231 | 318 |
| 24 | 196 | 60 | 39½ | 71 | 24 | 32 | 144 | 291 | 264 | 359 |
| 28 | 245 | 69 | 43½ | 75 | 24 | 36 | 160 | 344 | 300 | 399 |
| 32 | 277 | 119 | 47 | 79 | 28 | 40 | 173 | 384 | 342 | 449 |
| 36 | 307 | 130 | 51 | 83 | 28 | 44 | 189 | 418 | 384 | 495 |
| 40 | 333 | 142 | 55 | 87 | 28 | 48 | 205 | 448 | 420 | 535 |

All Dimensions are given in Inches.

**Floor Space required, Horizontal Coupled Engines, with and without Condensers.**

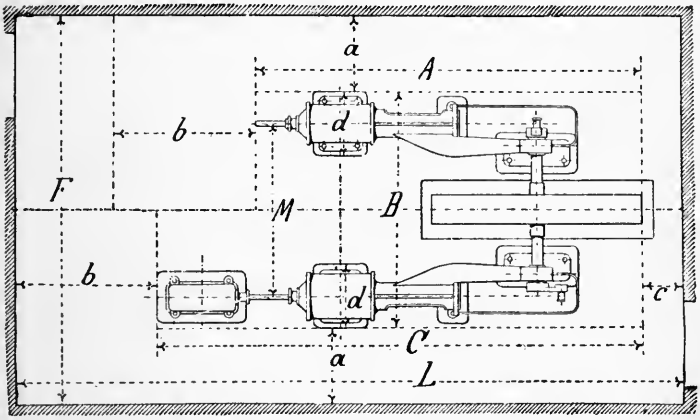



Fig. 908.

TABLE 92.—**Floor Space Dimensions for Horizontal Coupled Engines** (Fig. 908).

| H | A | B | M | *a* | *b* | *c* | *d* | F | C | L |
|---|---|---|---|---|---|---|---|---|---|---|
| 16 | — | 106 | 82 | 32 | 63 | 20 | 24 | 169 | — | — |
| 20 | 181 | 118 | 90 | 36 | 67 | 20 | 28 | 189 | 231 | 318 |
| 24 | 196 | 130 | 96 | 39½ | 71 | 24 | 32 | 209 | 264 | 359 |
| 28 | 245 | 142 | 104 | 43½ | 75 | 24 | 36 | 228 | 300 | 399 |
| 32 | 277 | 152 | 112 | 47 | 79 | 28 | 40 | 246 | 342 | 449 |
| 36 | 307 | 169 | 118 | 51 | 83 | 28 | 44 | 274 | 384 | 495 |
| 40 | 333 | 173 | 126 | 55 | 87 | 28 | 48 | 283 | 420 | 535 |

All Dimensions are given in Inches.

## Weights of Engines in Detail.

In the following tables—

CI = Cast iron. St = Mild steel.
WI = Wrought iron. CS = Cast steel.
M = White metal. G = Gun metal.
B = Bolts.

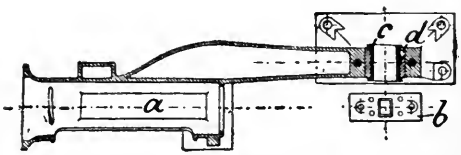



Fig. 909.

Fig. 910.

TABLE 93.—**Weights of Engine Frames and Crossheads.**

| Engine. | | Frame (Fig. 909). | | | | | | | | | Crosshead (Fig. 910). | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. H | Diameter of Piston. D | Frame. *a* | Bearing Cap. *b* | Brasses. *c* | Wedges. *d* | Frame complete with Bearing Cap. | | | | | Crosshead. *e* | Pin. *f* | Total. |
| | | CI | CI | G | WI | CI | G | WI | B | Total. | CI | St. | |
| 12 | 6 | 700 | — | — | — | 700 | — | — | — | 700 | 15 | 2 | 17 |
| 16 | 8 | 830 | 30 | 13 | — | 860 | 12 | — | 8 | 880 | 24 | 2 | 26 |
| 20 | 10 | 1060 | 57 | 18 | 11 | 1117 | 18 | 11 | 11 | 1157 | 42 | 4 | 46 |
| 24 | 12 | 1540 | 90 | 26 | 15 | 1630 | 26 | 15 | 15 | 1685 | 64 | 7 | 71 |
| 28 | 14 | 2100 | 140 | 37 | 17 | 2240 | 37 | 17 | 17 | 2310 | 90 | 11 | 101 |
| 32 | 16 | 2816 | 220 | 53 | 19 | 3036 | 53 | 19 | 18 | 3125 | 120 | 15 | 135 |
| 36 | 18 | 3740 | 290 | 70 | 22 | 4030 | 70 | 22 | 23 | 4145 | 155 | 19 | 174 |
| 40 | 20 | 5060 | 370 | 88 | 24 | 5430 | 88 | 24 | 23 | 5565 | 194 | 24 | 218 |
| 44 | 22 | 6600 | 470 | 110 | 28 | 7070 | 110 | 28 | 26 | 7234 | 234 | 31 | 265 |

Dimensions in Inches, Weights in Pounds.

## Weights of Engines.

### Pistons, and Piston Rods.

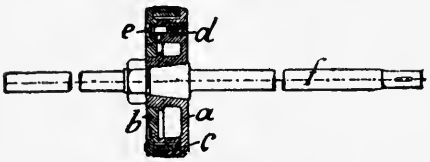



Fig. 911.

TABLE 94.—**Weights of Pistons and Piston Rods.**

| Engine. | | Fig. 911. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Piston body. *a* | Cover. *b* | Inner ring. *c* | Nuts. *d* | Screws. *e* | Piston rod. *f* | Piston complete with rod. *a* to *f* | | | |
| H | D | CI | CI | CI | G | St | St | CI | G | St | Total. |
| 12 | 6 | 15 | 4 | 9 | — | — | 7 | 28 | — | 7 | 35 |
| 16 | 8 | 20 | 7 | 13 | — | — | 13 | 40 | — | 13 | 53 |
| 20 | 10 | 26 | 10 | 18 | — | — | 24 | 55 | — | 24 | 79 |
| 24 | 12 | 33 | 18 | 24 | — | — | 57 | 75 | — | 57 | 132 |
| 28 | 14 | 44 | 26 | 30 | 4 | 4 | 88 | 100 | 4 | 92 | 196 |
| 32 | 16 | 66 | 40 | 40 | 4 | 4 | 121 | 146 | 4 | 125 | 275 |
| 36 | 18 | 92 | 57 | 57 | 7 | 7 | 154 | 206 | 7 | 161 | 374 |
| 40 | 20 | 121 | 73 | 68 | 7 | 7 | 200 | 262 | 7 | 207 | 476 |
| 44 | 22 | 179 | 95 | 92 | 9 | 9 | 286 | 366 | 9 | 295 | 570 |
| 48 | 24 | 220 | 128 | 125 | 11 | 11 | 396 | 473 | 11 | 407 | 891 |
| — | 28 | 330 | 187 | 191 | 13 | 15 | 726 | 708 | 13 | 741 | 1462 |
| — | 32 | 450 | 253 | 260 | 18 | 20 | 1188 | 963 | 18 | 1208 | 2189 |
| — | 36 | 572 | 330 | 338 | 22 | 26 | 1738 | 1240 | 22 | 1764 | 3026 |
| — | 40 | 720 | 418 | 429 | 26 | 33 | 2420 | 1567 | 26 | 2453 | 4046 |

Dimensions in Inches, Weights in Pounds.

## Weights of Engines.

### Crank Shafts, Fly Wheels and Outside Bearing.

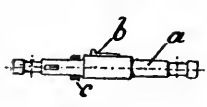



Fig. 912.

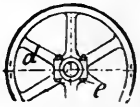



Fig. 913.

Fig. 914.

TABLE 95.—**Weights, Crank Shafts, Fly Wheels and Outside Bearings.**

| Engine. | | Crank Shaft (Fig. 912). | | | | Fly Wheel (Fig. 913). | | | Outside Bearing (Fig. 914). | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of Piston. | Shaft. *a* | Key. *b* | Governor Pulley. *c* | *a+b+c.* | Fly Wheel. *d* | Bolts and Rings. *e* | *d+e.* | Block and Cap. *f* | Brasses. *g* | Bolts *h* | *f+g+h.* |
| H | D | St | St | CI | Total. | CI | WI | Total. | CI | G | WI | Total. |
| 12 | 6 | — | — | — | — | 385 | — | 385 | — | — | — | — |
| 16 | 8 | — | — | — | — | 1045 | — | 1045 | — | — | — | — |
| 20 | 10 | 325 | 5·5 | 27·5 | 358 | 1650 | — | 1650 | 110 | 14 | 11 | 135 |
| 24 | 12 | 528 | 8 | 39 | 575 | 2530 | — | 2530 | 242 | 24 | 18 | 284 |
| 28 | 14 | 836 | 10 | 54 | 900 | 3520 | 44 | 3564 | 352 | 35 | 23 | 410 |
| 32 | 16 | 1255 | 14 | 66 | 1335 | 5012 | 48 | 5060 | 462 | 48 | 32 | 542 |
| 36 | 18 | 1760 | 15 | 80 | 1855 | 6548 | 52 | 6600 | 554 | 62 | 44 | 660 |
| 40 | 20 | 2244 | 18 | 92 | 2354 | 8963 | 57 | 9020 | 660 | 77 | 55 | 792 |
| 44 | 22 | 3256 | 24 | 110 | 3390 | 13138 | 62 | 13200 | 770 | 88 | 66 | 824 |

Dimensions in Inches, Weight in Pounds.

## Weights of Engines.

### Rider's Valves and Valve Rods.

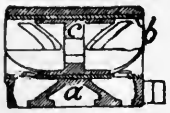



Fig. 915.

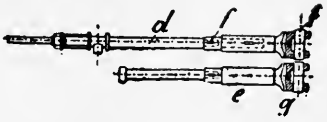



Fig. 916.

TABLE 96.—**Weight of Rider's Valves and Valve Rods.**

| Engine. | | Rider's valve, fig. 915. | | | | Valve rods, fig. 916. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Main valve. | Case. | Expansion valve. | $a+b+c$. | Valve rod. | Guide piece. | Cotters and bolts. | Adjusting pieces. | $d+e+f+g$. |
| | | $a$ | $b$ | $c$ | | $d$ | $e$ | $f$ | $g$ | |
| H | D | CI | CI | CI | Total. | St | WI | St | G | Total. |
| 12 | 6 | — | — | — | — | 7 | 9 | 1 | 1 | 18 |
| 16 | 8 | — | — | — | — | 9 | 13 | 1 | 1 | 24 |
| 20 | 10 | 42 | 6·6 | 4·4 | 53 | 13 | 22 | 2 | 1 | 38 |
| 24 | 12 | 66 | 13 | 9 | 88 | 18 | 35 | 2 | 1 | 56 |
| 28 | 14 | 100 | 22 | 15 | 137 | 24 | 52 | 3 | 3 | 82 |
| 32 | 16 | 145 | 33 | 26 | 204 | 31 | 70 | 4 | 5 | 110 |
| 36 | 18 | 194 | 46 | 35 | 275 | 40 | 88 | 7 | 5 | 140 |
| 40 | 20 | 242 | 62 | 48 | 352 | 48 | 105 | 7 | 5 | 165 |
| 44 | 22 | 290 | 84 | 66 | 440 | 57 | 123 | 8 | 5 | 193 |

Dimensions in Inches, Weights in Pounds.

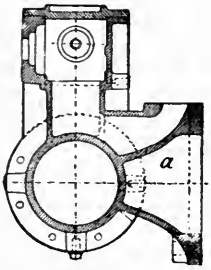



Fig. 917.

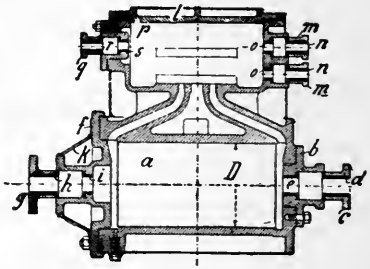



Fig. 918.

TABLE 97.—**Weights of Cylinders with**

| Engine. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke | Diameter of piston. | Cylinder. | Front cover. | Gland. | Bush. | Bush. | Back cover. | Gland. | Bush. | Bush. | Casing. | Valve chest covers. |
| | | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* |
| H | D | CI | CI | CI | G | G | CI | CI | G | G | CI | CI |
| 12 | 6 | 286 | 13 | 4 | 0·7 | 0·4 | 22 | — | — | — | — | 13 |
| 16 | 8 | 475 | 22 | 7 | 1·2 | 0·7 | 40 | — | — | — | — | 28 |
| 20 | 10 | 690 | 35 | 9 | 1·5 | 1·2 | 59 | — | — | — | — | 72 |
| 24 | 12 | 1090 | 48 | 11 | 2·2 | 1·5 | 90 | 11 | 2·5 | 1·1 | 22 | 75 |
| 28 | 14 | 1540 | 64 | 14 | 2·8 | 2·2 | 143 | 15 | 3·5 | 1·5 | 26 | 134 |
| 32 | 16 | 2125 | 80 | 15 | 3·5 | 2·6 | 200 | 19 | 4 | 1·9 | 40 | 194 |
| 36 | 18 | 2860 | 94 | 18 | 4·2 | 3·3 | 308 | 24 | 4·5 | 2·4 | 48 | 275 |
| 40 | 20 | 3520 | 112 | 22 | 4·8 | 3·7 | 440 | 30 | 5 | 3·0 | 57 | 335 |
| 44 | 22 | 4225 | 132 | 26 | 5·5 | 4·4 | 572 | 37 | 5·5 | 3·7 | 66 | 400 |

Dimensions in Inches, Weights in Pounds.

## Weights of Cylinders, Covers and Stuffing Boxes.

Note: in Table 97, Cylinders from 12″ to 16″ stroke have simple valve gear; those from 20″ to 44″ stroke have Rider's valve gear with closed valves.

**Covers and Stuffing Boxes** (Figs. 917, 918).

| Gland. *m* | Bush. *n* | Bush. *o* | Stuffing-box. *p* | Gland. *q* | Bush. *r* | Bush. *s* | Casing. *t* | Cylinder complete with covers and glands. *a*+&c.+*t* | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CI | G | G | CI | GI | G | G | WI | CI | G | WI | B | Total. |
| — | — | — | — | — | — | — | 7 | 338 | 1·1 | 7 | 11 | 357 |
| — | — | — | — | — | — | — | 13 | 572 | 1·9 | 13 | 22 | 608 |
| 7 | 1·3 | 0·9 | 15 | 3 | 0·4 | 0·4 | 22 | 860 | 5·7 | 22 | 31 | 919 |
| 7 | 1·5 | 1·1 | 24 | 4 | 0·4 | 0·4 | 40 | 1382 | 11 | 40 | 42 | 1475 |
| 9 | 1·8 | 1·1 | 30 | 5 | 0·7 | 0·4 | 57 | 1980 | 14 | 57 | 55 | 2106 |
| 11 | 2·0 | 1·3 | 37 | 6 | 0·9 | 0·4 | 81 | 2727 | 17 | 81 | 70 | 2895 |
| 13 | 2·2 | 1·3 | 46 | 7 | 0·9 | 0·7 | 105 | 3693 | 19 | 105 | 88 | 3905 |
| 15 | 2·4 | 1·5 | 52 | 8 | 1·1 | 0·7 | 132 | 4591 | 22 | 132 | 102 | 4847 |
| 18 | 2·6 | 1·5 | 62 | 9 | 1·1 | 0·9 | 160 | 5547 | 25 | 160 | 119 | 5851 |

*Note.*—Cylinders with jackets weigh 18 per cent. more.

## Weights of Engines.

### Connecting Rods, Cranks, and Crank Pins.

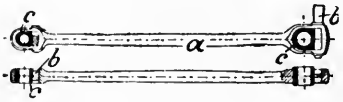



Fig. 919

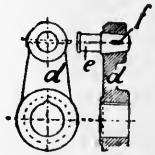



Fig. 920.

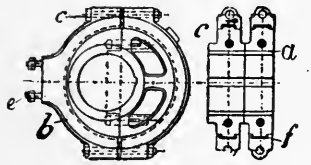
TABLE 98.—**Weights of Connecting Rods, Cranks, and Crank Pins.**

| Engine. | | Connecting-rods, fig. 919. | | | | Cranks and crank-pins, fig. 920. | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Connecting-rod. *a* | Cotter. *b* | Brasses. *c* | *a*+*b*+*c*. | Crank. *d* | Crank-pin. *e* | Cotter. *f* | *d*+*e*+*f*. |
| H | D | WI | St | G | Total. | WI | St | St | Total. |
| 12 | 6 | 24 | 3 | 3 | 30 | — | — | — | — |
| 16 | 8 | 42 | 3 | 5 | 50 | — | — | — | — |
| 20 | 10 | 66 | 7 | 9 | 82 | 70 | 12 | 2 | 84 |
| 24 | 12 | 100 | 7 | 11 | 118 | 119 | 17 | 2 | 138 |
| 28 | 14 | 142 | 9 | 13 | 164 | 176 | 23 | 4 | 203 |
| 32 | 16 | 187 | 11 | 18 | 216 | 238 | 34 | 6 | 278 |
| 36 | 18 | 265 | 13 | 24 | 302 | 308 | 52 | 6 | 366 |
| 40 | 20 | 319 | 15 | 33 | 367 | 376 | 55 | 9 | 440 |
| 44 | 22 | 385 | 15 | 44 | 444 | 462 | 70 | 11 | 543 |

*Note.*—Cast-iron cranks are about 20% heavier.
Dimensions in Inches, Weights in Pounds.

## Weights of Engines.

### Eccentrics and Eccentric Rods.




Figs. 921, 922.

Fig. 923.

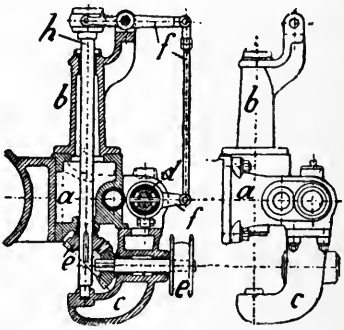
TABLE 99.—**Weights of Two Eccentrics and Rods.**

| Engine. | | Two eccentrics, figs. 921, 922. | | | | | | | Two eccentric rods, fig. 923. |
|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Eccentric sheaves. *a* | Eccentric rings. *b* | Bolts. *c* | Packings. *d* | Bolts. *e* | Linings. *f* | Two eccentrics complete *a* to *f* | *g* |
| H | D | CI | CI | WI | G | WI | M | Total. | WI |
| 12 | 6 | 10 | 19 | — | 0·4 | 1·1 | — | 30·5 | 9 |
| 16 | 8 | 12 | 25 | — | 0·4 | 2·6 | — | 40 | 15 |
| 20 | 10 | 18 | 35 | 1·5 | 0·7 | 3 | 6·6 | 64·8 | 22 |
| 24 | 12 | 31 | 64 | 2 | 0·9 | 4 | 13 | 115 | 38 |
| 28 | 14 | 44 | 109 | 2 | 1 | 5 | 20 | 172 | 60 |
| 32 | 16 | 62 | 145 | 3 | 1 | 7 | 26 | 244 | 92 |
| 36 | 18 | 77 | 202 | 4 | 1 | 7 | 30 | 321 | 125 |
| 40 | 20 | 97 | 257 | 5 | 1·4 | 7·6 | 40 | 408 | 158 |
| 44 | 22 | 121 | 320 | 5 | 1·5 | 8·5 | 44 | 500 | 194 |

Dimensions in Inches, Weights in Pounds.

## Weights of Engines.

### Valve Rod Guides, with Governor Bracket, Bevel Wheels, Spindles, and Levers, exclusive of Governor and Spindle.




Figs. 924, 925.

TABLE 100.—**Weights of Governor Bracket, &c.** (Figs. 924, 925).

| Engine. | | Valve-rod guides. | Governor bracket. | Bracket for footstep. | Bevel wheels and pulley. | Lever. | Spindle. | Bushes. | Weight complete, as in figs. 924, 925. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | *a* | *b* | *c* | *e* | *f* | *g* | *d* | *a* to *g* | | | | | |
| H | D | CI | CI | CI | CI | WI | St | G | CI | G | WI | St | B | Total. |
| 20 | 10 | 70 | 26 | 33 | 18 | 31 | 11 | 7 | 160 | 18 | 11 | 7 | 4 | 200 |
| 24 | 12 | 121 | 40 | 40 | 24 | 37 | 15 | 7 | 238 | 24 | 15 | 7 | 7 | 291 |
| 28 | 14 | 165 | 50 | 46 | 33 | 44 | 22 | 9 | 305 | 33 | 22 | 9 | 9 | 378 |
| 32 | 16 | 215 | 66 | 53 | 40 | 53 | 26 | 9 | 387 | 40 | 26 | 9 | 11 | 473 |
| 36 | 18 | 268 | 84 | 62 | 46 | 59 | 33 | 11 | 473 | 46 | 33 | 11 | 13 | 576 |
| 40 | 20 | 325 | 103 | 68 | 53 | 64 | 37 | 11 | 560 | 53 | 37 | 11 | 15 | 676 |
| 44 | 22 | 375 | 121 | 77 | 62 | 70 | 44 | 13 | 643 | 62 | 44 | 13 | 18 | 780 |

Dimensions in Inches, Weights in Pounds.

## Weights of Engines.

### Foundation Bolts and Plates, Guard Rail, and Barring Apparatus.

Fig. 926.

Fig. 927.

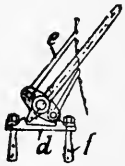



Fig. 928.

TABLE 101.—**Weights of Foundation Bolts, &c.**

| Engine. | | Foundation bolts and plates, fig. 926. | | | Guard rail, fig. 927. | Barring apparatus, fig. 928. | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Plates. *b* | Bolts. *a* | *b*+*a* | *c* | Bracket. *d* | Lever. *e* | Lewis bolts. *f* | Barring apparatus complete. *d*+*e*+*f* |
| | | CI | WI | Total. | WI | CI | WI | WI | Total. |
| 12 | 6 | 44 | 35 | 79 | — | — | — | — | — |
| 16 | 8 | 44 | 48 | 92 | — | — | — | — | — |
| 20 | 10 | 140 | 66 | 206 | 11 | 44 | 22 | 13 | 79 |
| 24 | 12 | 176 | 132 | 308 | 15 | 44 | 22 | 13 | 79 |
| 28 | 14 | 330 | 198 | 528 | 22 | 55 | 26 | 18 | 99 |
| 32 | 16 | 396 | 264 | 660 | 29 | 55 | 26 | 18 | 99 |
| 36 | 18 | 616 | 352 | 968 | 35 | 77 | 35 | 26 | 158 |
| 40 | 20 | 616 | 440 | 1056 | 44 | 77 | 35 | 26 | 158 |
| 44 | 22 | 748 | 550 | 1290 | 55 | 77 | 35 | 26 | 158 |

Dimensions in Inches, Weights in Pounds.

TABLE 102.—**Summary of the Tables of Weights, 92 to 101.**

| Engine. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Stroke. | Diameter of piston. | Cast-iron. | Gun-metal. | Wrought-iron. | Steel | Bolts. | Weight without fly-wheel or governor. | Governor. | Fly-wheel. | Sundry fittings, valves, &c. | Weight with Rider's valve gear without condenser. | Condenser. | Weight with Condenser. | Feed-pump with eccentric. |
| H | D | CI | G | WI | St | WI | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. | lbs. |
| 20 | 10 | 2663 | 66 | 326 | 405 | 75 | 3535 | 110 | 1650 | 66 | 5361 | — | — | 88 |
| 24 | 12 | 4073 | 97 | 532 | 651 | 100 | 5453 | 176 | 2530 | 88 | 8247 | 1760 | 10007 | 110 |
| 28 | 14 | 5787 | 140 | 774 | 1020 | 125 | 7846 | 242 | 3564 | 110 | 11762 | 3080 | 14842 | 155 |
| 32 | 16 | 7806 | 185 | 1038 | 1502 | 158 | 10689 | 308 | 5060 | 155 | 16212 | 3520 | 19732 | 220 |
| 36 | 18 | 10428 | 233 | 1355 | 2075 | 200 | 14291 | 374 | 6600 | 176 | 21441 | 4400 | 25841 | 308 |
| 40 | 20 | 13188 | 287 | 1676 | 2625 | 230 | 18006 | 462 | 9020 | 198 | 27686 | 5500 | 33186 | 418 |
| 44 | 22 | 16380 | 343 | 2045 | 3782 | 264 | 22814 | 550 | 13200 | 220 | 36734 | 6600 | 43384 | 528 |
| Per cent. of material | | 75·5 | 1·8 | 9·2 | 11·4 | 2·1 | 100 | Without fly-wheel for engines up to 20″ stroke. | | | | | | |
| | | 71·9 | 1·5 | 8·9 | 16·5 | 1·2 | 100 | ,, | | ,, | | ,, | | 44″ stroke. |

Dimensions in Inches, Weights in Pounds.

TABLE 103.—**Cost of Patterns, complete with Core Boxes. For Engines of 20 to 44 Inches stroke, with Rider's Valve Gear.**

| Stroke | 20 | 24 | 28 | 32 | 36 | 40 | 44 |
|---|---|---|---|---|---|---|---|
| Diameter of piston | 10 | 12 | 14 | 16 | 18 | 20 | 22 |
| Frame with bearing cap and brasses | 250 | 264 | 285 | 300 | 320 | 350 | 390 |
| Crosshead | 25 | 30 | 38 | 44 | 50 | 60 | 65 |
| Connecting-rod brasses | 5 | 6 | 7 | 8 | 9 | 10 | 12 |
| Cylinder with cover and glands | 195 | 210 | 220 | 240 | 260 | 280 | 300 |
| Piston with rings and cover | 24 | 26 | 29 | 31 | 35 | 40 | 45 |
| Outside main bearing | 33 | 36 | 41 | 46 | 55 | 60 | 70 |
| Rider's valve | 70 | 75 | 80 | 85 | 95 | 105 | 115 |
| Adjusting nuts for valve gear | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| Eccentrics with rings | 30 | 35 | 40 | 45 | 50 | 57 | 65 |
| Valve rod guides with governor bracket, bevel wheels and pulley | 70 | 80 | 90 | 105 | 115 | 130 | 150 |
| Foundation plates | 3 | 3 | 3·5 | 3·5 | 3·5 | 3·5 | 3·5 |
| Barring apparatus | 9 | 9 | 10·5 | 10·5 | 12·5 | 12·5 | 12·5 |
| Feed pump | 120 | 130 | 140 | 150 | 160 | 170 | 185 |
| Total cost of patterns | 835 | 905 | 985 | 1070 | 1165 | 1280 | 1415 |

The dimensions are given in inches, the cost in marks, the value of a mark being about 11¾ English pence.
The patterns admit of the engine being built either right or left-handed.

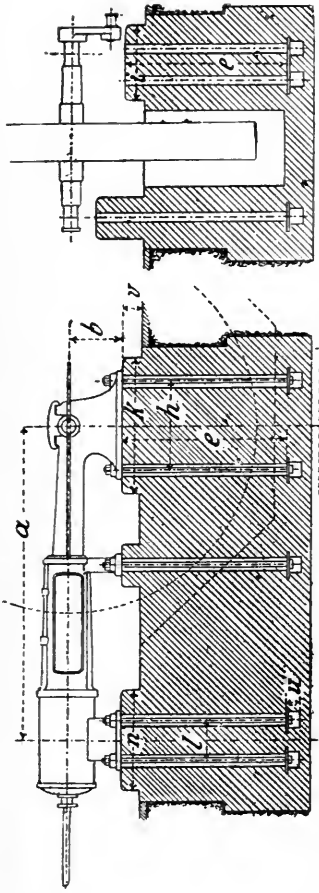



Fig. 930.

Fig. 931.

Fig. 929.

TABLE 104.—**Dimensions of Engine Foundations for Horizontal Engines** (Figs. 929—931).

| H | D | *a* | *b* | *c* | *d* | *e* | *f* | *g* | *h* | *i* | *k* | *l* | *m* | *n* | *o* | *p* | *q* | *r* | *u* | *w* | *x* | M* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 10 | 76 | 14½ | 51 | 9 | 55 | 7 | 2 | 22 | 20½ | 36¼ | — | 15½ | 23⅝ | 23⅝ | — | — | — | 4 | 39½ | 15¾ | 6·5 |
| 24 | 12 | 90 | 18 | 57 | 10⅝ | 63 | 8 | 2¼ | 25⅝ | 20½ | 41 | 13¾ | 17¾ | 27¾ | 27¾ | — | — | — | 4¾ | 43½ | 16¾ | 10·5 |
| 28 | 14 | 106 | 20 | 63 | 12½ | 71 | 9 | 2¾ | 30 | 26 | 46½ | 15¾ | 20½ | 31½ | 31½ | — | — | — | 5½ | 47½ | 17¾ | 14·4 |
| 32 | 16 | 121½ | 22 | 70 | 14 | 75 | 10¼ | 3⅜ | 34 | 31 | 52 | 17¾ | 22¾ | 35½ | 35½ | 20½ | 35½ | 20 | 6¼ | 52 | 18¾ | 19·6 |
| 36 | 18 | 135 | 24 | 75 | 15½ | 79 | 11¾ | 4 | 37 | 31 | 57 | 18¾ | 25¼ | 39½ | 39½ | 22¼ | 38⅝ | 20¾ | 7 | 55 | 19¾ | 26 |
| 40 | 20 | 151 | 26 | 82 | 17 | 84 | 12½ | 4⅜ | 40½ | 36⅝ | 62 | 20 | 27¾ | 43½ | 43½ | 22¾ | 42 | 22¼ | 8 | 60 | 20¾ | 32·7 |
| 44 | 22 | 168 | 28 | 90 | 18½ | 90 | 14 | 5 | 44½ | 36⅝ | 69 | 21¾ | 29½ | 47½ | 47½ | 25¼ | 46 | 23⅝ | 8 | 64 | 21¾ | 39·3 |

* (M), the contents of Foundations in Cubic Yards; all other Dimensions in Inches.

## Engine Foundations.

The depth of is in some measure determined by the nature of the ground. It may be necessary to go down a great depth to reach a solid basis whereon to build, and to fill up with coarse concrete up to the level of the foundation bolts and then begin the foundation proper. The material depends on the district; in some districts concrete is the most ready material, in others brick or masonry. In cases where a building for manufacturing purposes has to be erected on very loose ground and where concrete is easily obtained, it is a good plan to floor the whole area occupied by factory, engine and boiler house with a bed of concrete of sufficient thickness, and to build all structures on this bed. Settlement is very unlikely to take place with such a system, as the weight is distributed over the largest possible area of the loose ground.

For brick foundations each course should be grouted in thoroughly with good cement, and all bolt holes formed by inserting wood bars about 3″ to 4″ square, the lower end of these resting in the foundation plates, and the upper ends in a template fixed in places; the wood bars are afterwards withdrawn and the bolts inserted. When the engine is in place and bolted down, the spaces round the bolts may be filled in with cement grout. In concrete the same plan with regard to the bolt holes may be used.

With masonry foundations the holes are usually cut through. A top course of stone is very good on brick foundations, but is expensive in districts far from the quarries.

When the first motion drive from the engine is through spur or bevel wheels, great care should be taken with the foundations, and if of concrete as much time as possible should be allowed after building before the engine is started. The most convenient form of foundation bolt is perhaps the cottar bolt, as it can be passed down the hole in the foundation without trouble, and should such an accident happen as a defective bolt, it can be replaced. In small work ordinary bolts with heads and nuts are much used, being built in the foundation.

---

*Note.*—The particulars given in Tables 85 to 104, and the corresponding illustrations, are from engines of continental make, and are given exactly as they appear in the 3rd edition of M. Haeder's book, "Die Dampfmaschine," except that the dimensions are converted into English measures.

# SECTION VII.

## PARTICULARS OF STANDARD ENGINES BY ENGLISH MAKERS.

The following Tables, 105 to 129, give the particulars of small and medium-sized engines by English makers who manufacture large numbers of these engines, and have given every attention to details of construction and design ; they may therefore be taken as examples of best English practice in the various types of which tables and illustrations are given.

Descriptions of some of the special valve gears applied to these engines are given in the Section on Valve Gears, and examples of indicator diagrams from actual practice are given in the Section on Indicator Diagrams.

The particulars in each table were supplied by the makers themselves.

TABLE 105.—**Particulars of Messrs. Ransomes, Sims & Jefferies' Long-Stroke Horizontal Engine without Condenser** (Fig. 932).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Length of stroke | 20 | 20 | 24 | 24 | 28 | 28 | 32 | 32 | 36 | 36 |
| Revolutions per minute | 110 | 110 | 90 | 90 | 80 | 80 | 70 | 70 | 60 | 60 |
| Boiler-pressure per □″ | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Best average H.P. | 30 | 40 | 45 | 55 | 65 | 75 | 85 | 95 | 100 | 115 |
| Diameter of crank-shaft | 4 | 4¼ | 4¾ | 5 | 5⅝ | 5⅞ | 6½ | 6¾ | 7¼ | 7½ |
| Diameter of fly-wheel | 84 | 84 | 96 | 96 | 108 | 108 | 120 | 120 | 144 | 144 |
| Width of fly-wheel | 8 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 |
| Weight of fly-wheel, cwts. | 24 | 24 | 46 | 46 | 60 | 60 | 90 | 90 | 110 | 110 |
| Height to centre of cylinder | 16½ | 16½ | 19 | 19 | 22 | 22 | 23 | 23 | 30 | 30 |
| Total length, including fly-wheel | 153 | 153 | 181 | 181 | 210 | 210 | 238 | 238 | 281 | 281 |
| Total width to outer bearing | 74 | 74 | 82½ | 82½ | 96 | 96 | 107 | 107 | 131 | 131 |
| Approx. weight packed, cwts. | 72 | 76 | 106 | 112 | 163 | 172 | 218 | 230 | 291 | 307 |

All Dimensions are given in Inches.

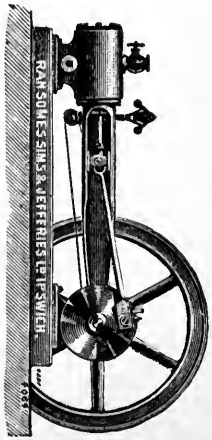



Fig. 932.

TABLE 106.—**Particulars of Messrs. Ransomes, Sims & Jefferies' Long-Stroke Engine with Condenser** (Fig. 933).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Length of stroke | 20 | 20 | 24 | 24 | 28 | 28 | 32 | 32 | 36 | 36 |
| Revolutions per minute | 110 | 110 | 90 | 90 | 80 | 80 | 70 | 70 | 60 | 60 |
| Boiler pressure | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Best average H.P. | 40 | 50 | 55 | 65 | 80 | 90 | 105 | 115 | 125 | 140 |
| Diameter of fly-wheel | 84 | 84 | 96 | 96 | 108 | 108 | 120 | 120 | 144 | 144 |
| Width of fly-wheel | 8 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 |
| Weight of fly-wheel, cwts. | 24 | 24 | 46 | 46 | 60 | 60 | 90 | 90 | 110 | 110 |
| Diameter of crank-shaft | 4 | $4\frac{1}{4}$ | $4\frac{3}{4}$ | 5 | $5\frac{5}{8}$ | $5\frac{7}{8}$ | $6\frac{1}{2}$ | $6\frac{3}{4}$ | $7\frac{1}{4}$ | $7\frac{1}{2}$ |
| Diameter of air-pump bucket | 4 | 4 | 4 | 4 | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | $5\frac{1}{2}$ | 7 | 7 |
| Height to centre of cylinder | $16\frac{1}{2}$ | $16\frac{1}{2}$ | 19 | 19 | 22 | 22 | 23 | 23 | 30 | 30 |
| Total length, including fly-wheel | 241 | 241 | 272 | 272 | 313 | 313 | 345 | 345 | 420 | 420 |
| Width to outer bearing | $78\frac{1}{2}$ | $78\frac{1}{2}$ | 87 | 87 | 102 | 102 | 111 | 111 | 135 | 135 |
| Approx. weight packed, cwts. | 89 | 93 | 126 | 132 | 188 | 197 | 257 | 269 | 348 | 364 |

All Dimensions are given in Inches.

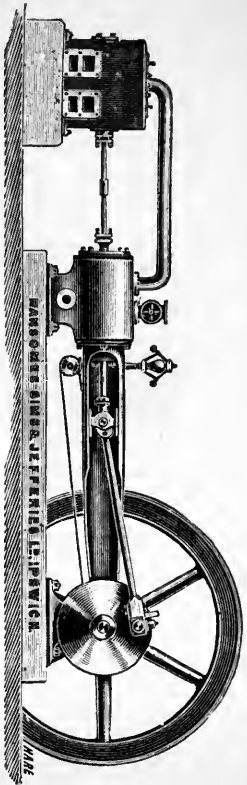



Fig. 933.

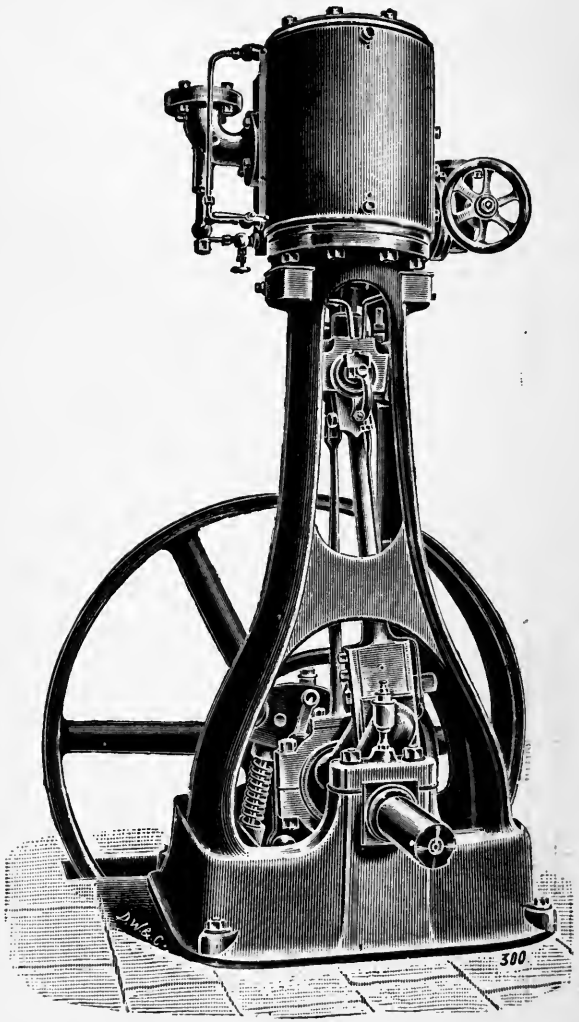



Fig. 934.

TABLE 107.—**Particulars of Messrs. Marshall's Vertical Short-Stroke Engines** (Fig. 934).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{2}$ | 8 | 9 | 10 | 11 | 12 | 13 |
| Stroke | 8 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 |
| Revolutions per minute | 260 | 260 | 210 | 210 | 175 | 175 | 150 | 150 | 130 | 130 |
| Boiler-pressure, lbs. per □″ | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Best average H.P.* | 5 | $7\frac{1}{2}$ | $10\frac{1}{2}$ | $13\frac{3}{4}$ | 16 | 20 | 25 | $30\frac{1}{2}$ | 36 | 42 |
| Diameter of fly-wheel | 32 | 32 | $41\frac{1}{2}$ | $41\frac{1}{2}$ | $52\frac{1}{2}$ | $52\frac{1}{2}$ | 60 | 60 | 66 | 66 |
| Width of fly-wheel | 5 | 5 | 6 | 6 | $7\frac{1}{2}$ | $7\frac{1}{2}$ | $9\frac{1}{2}$ | $9\frac{1}{2}$ | $11\frac{1}{4}$ | $11\frac{1}{4}$ |
| Weight of fly-wheel, cwts. | $2\frac{1}{4}$ | $2\frac{1}{4}$ | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $7\frac{3}{4}$ | $7\frac{3}{4}$ | 11 | 11 | 17 | 17 |
| Diameter of crank-shaft | $2\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{3}{4}$ | $2\frac{3}{4}$ | $3\frac{1}{4}$ | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{1}{2}$ | $4\frac{1}{2}$ |
| Total height of engine | $55\frac{5}{16}$ | $55\frac{5}{16}$ | $66\frac{1}{4}$ | $66\frac{1}{4}$ | $78\frac{1}{8}$ | $78\frac{1}{8}$ | $89\frac{1}{4}$ | $89\frac{1}{4}$ | $105\frac{1}{8}$ | $105\frac{1}{8}$ |
| Floor space, width† | 32 | 32 | $41\frac{1}{2}$ | $41\frac{1}{2}$ | $52\frac{1}{2}$ | $52\frac{1}{2}$ | 60 | 60 | 66 | 66 |
| Floor space, length† | $43\frac{1}{2}$ | $43\frac{1}{2}$ | 52 | 52 | 63 | 63 | 70 | 70 | 70 | 70 |
| Height of centre from ground | $8\frac{1}{2}$ | $8\frac{1}{2}$ | 10 | 10 | $11\frac{1}{2}$ | $11\frac{1}{2}$ | $13\frac{1}{2}$ | $13\frac{1}{2}$ | 15 | 5 |

*Effective H.P. † Including space for fly-wheel.

All Dimensions are given in Inches.

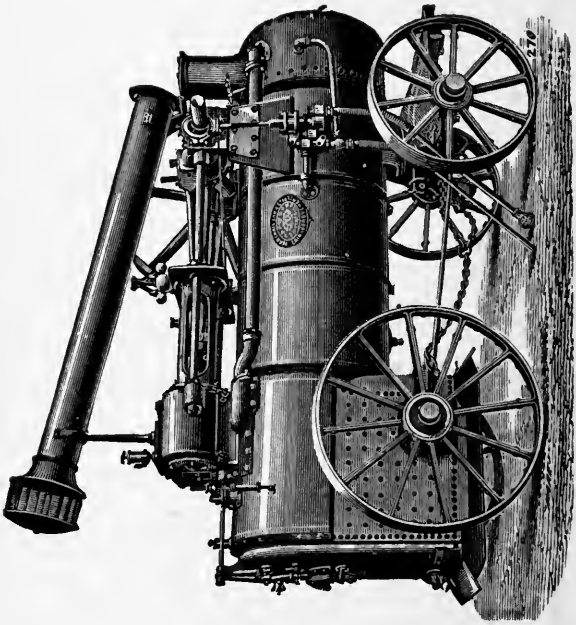


Fig. 935.

TABLE 108.—**Particulars of Messrs. Marshall's Double Cylinder Portable Engines** (Fig. 935).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nominal horse-power | 14 | 16 | 20 | 25 | 30 | 35 | 40 |
| Diameter of cylinders (each) | 9 | 10 | 11 | 12 | 13 | $13\frac{3}{4}$ | $14\frac{1}{2}$ |
| Length of stroke | 14 | 14 | 16 | 16 | 18 | 18 | 20 |
| Revolutions per minute | 115 | 115 | 95 | 95 | 85 | 85 | 80 |
| Boiler pressure per □″ | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| Best average H.P. | 35 | 40 | 50 | 63 | 75 | 88 | 100 |
| Diameter of crank-shaft | 4 | 4 | $4\frac{3}{4}$ | 5 | $5\frac{1}{2}$ | 6 | $6\frac{1}{4}$ |
| Diameter of fly-wheel | 67 | 67 | 72 | 72 | 79 | 79 | 99 |
| Width of fly-wheel | $9\frac{1}{2}$ | $9\frac{1}{2}$ | 13 | 13 | 15 | 15 | 15 |
| Weight of fly-wheel in cwts. | 11 | 11 | $15\frac{1}{4}$ | $15\frac{1}{4}$ | 19 | 19 | 30 |
| Total heating-surface of boiler, ordinary, sq. feet | 280·52 | 314·59 | 389·81 | 422·62 | 471·092 | 560·907 | 622·685 |
| Total heating-surface of boiler, colonial, sq. feet | 285·73 | 321·94 | 395·32 | 429·241 | 479·177 | 569·114 | 633·683 |
| Area of grate, ordinary | 9·04 | 9·68 | 12·69 | 13·810 | 15·265 | 17·747 | 20·035 |
| Area of grate, colonial | 10·74 | 11·93 | 14·34 | 15·910 | 17·747 | 20·285 | 23·411 |
| Diameter of boiler barrel | $40\frac{3}{4}$ | $42\frac{3}{4}$ | 45 | $49\frac{1}{8}$ | 51 | 51 | 55 |
| Total length of boiler, ordinary | 150 | 158 | $174\frac{1}{4}$ | 178 | 189 | 203 | 211 |
| Total length of boiler, colonial | 157 | 167 | 180 | 185 | 197 | 211 | 221 |
| Length of boiler barrel | $91\frac{1}{2}$ | 94 | $100\frac{1}{4}$ | 100 | 105 | 111 | 115 |

All Dimensions are given in Inches.

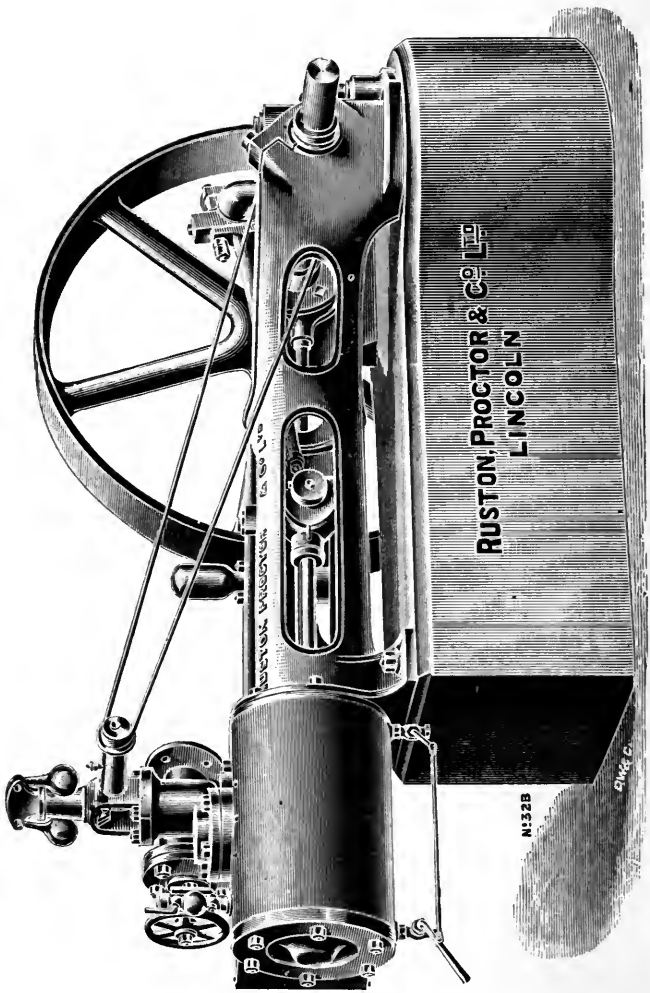



Fig. 936.

TABLE 109.—**Particulars of Messrs. Ruston & Proctor's Horizontal Self-Contained Short-Stroke Engines** (Fig. 936).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder | 5½ | 6½ | 7¼ | 8 | 8¾ | 9½ | 10½ | 11½ |
| Length of stroke | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 |
| Revolutions per minute | 190 | 160 | 160 | 140 | 140 | 125 | 125 | 110 |
| Boiler pressure, lbs. per square inch | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Best average H.P. | 7 | 11 | 13 | 17 | 20 | 24 | 30 | 36 |
| Diameter of crank-shaft | 2 | 2¼ | 2½ | 2¾ | 3 | 3¼ | 3½ | 3¾ |
| Diameter of fly-wheel | 33 | 36 | 39 | 40 | 45 | 48 | 54 | 60 |
| Width of fly-wheel | 4½ | 4½ | 5 | 5 | 6 | 6 | 7 | 7½ |
| Weight in cwts. | 2 | 2½ | 3 | 3½ | 4¼ | 5¼ | 6¾ | 8 |
| Height to centre | 17 | 18 | 18 | 28 | 28 | 30 | 30 | 30 |
| Total length | 64 | 74 | 76 | 88 | 89 | 100 | 103 | 116 |
| Total width | 32 | 36 | 36 | 42 | 44 | 50 | 52 | 60 |
| Approx. weight unpacked, cwts. | 7 | 9 | 11 | 15 | 17 | 24 | 27 | 35 |

All Dimensions are given in Inches.

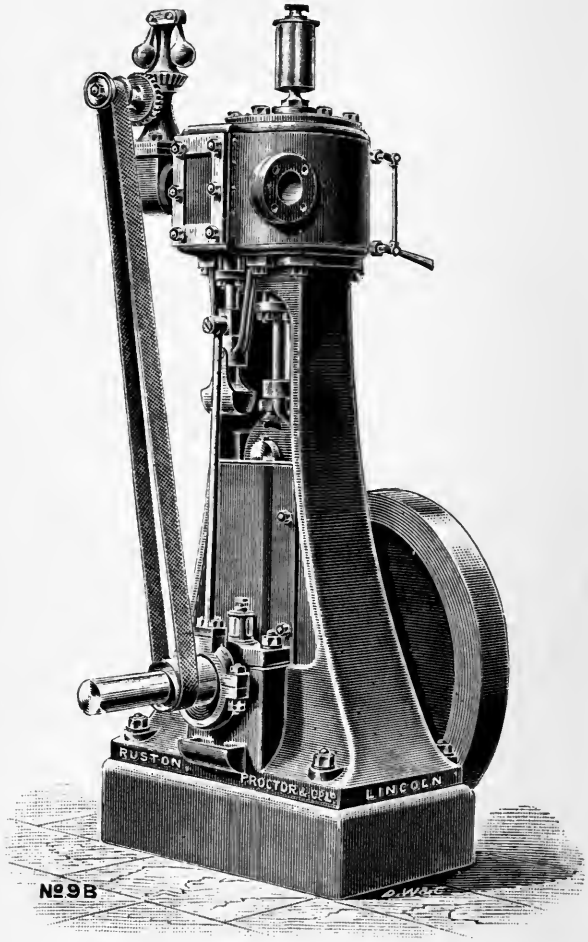



Fig. 937.

TABLE 110.—**Particulars of Messrs. Ruston & Proctor's Vertical Short-Stroke Engines** (Fig. 937).

| Diameter of cylinder | 6 | | | $6\frac{3}{4}$ | | | $7\frac{1}{2}$ | | | $8\frac{1}{2}$ | | | $9\frac{1}{2}$ | | | $10\frac{1}{2}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of stroke | 6 | | | 6 | | | 8 | | | 8 | | | 10 | | | 10 | | |
| Revolutions per minute | 150 | 200 | 250 | 150 | 200 | 250 | 150 | 200 | 250 | 150 | 200 | 250 | 150 | 200 | 250 | 150 | 200 | 250 |
| Best average H.P. | 5 | 7 | 9 | 7 | 9 | 11 | 10 | 14 | 18 | 14 | 18 | 23 | 22 | 29 | 36 | 27 | 35 | 44 |
| Boiler pressure, lbs. per sq. in. | 80 | | | 80 | | | 80 | | | 80 | | | 80 | | | 80 | | |
| Diameter of fly-wheel | 30 | | | 30 | | | 33 | | | 33 | | | 42 | | | 42 | | |
| Width of fly-wheel | 4 | | | 5 | | | $4\frac{1}{2}$ | | | 6 | | | 6 | | | 8 | | |
| Weight of fly-wheel in cwts. | 2 | | | $3\frac{1}{2}$ | | | 5 | | | 6 | | | $7\frac{1}{2}$ | | | 9 | | |
| Diameter of crank-shaft | $2\frac{1}{4}$ | | | $2\frac{1}{2}$ | | | 3 | | | $3\frac{1}{4}$ | | | $3\frac{1}{2}$ | | | $3\frac{3}{4}$ | | |
| Total width of engine | 30 | | | 30 | | | 33 | | | 33 | | | 42 | | | 42 | | |
| Total height from ground | 57 | | | 57 | | | 66 | | | 66 | | | 78 | | | 78 | | |
| Total length | 34 | | | 34 | | | 40 | | | 40 | | | 48 | | | 48 | | |
| Approx. weight in cwts. | 12 | | | 14 | | | 16 | | | 17 | | | 20 | | | 22 | | |

All Dimensions are given in Inches.

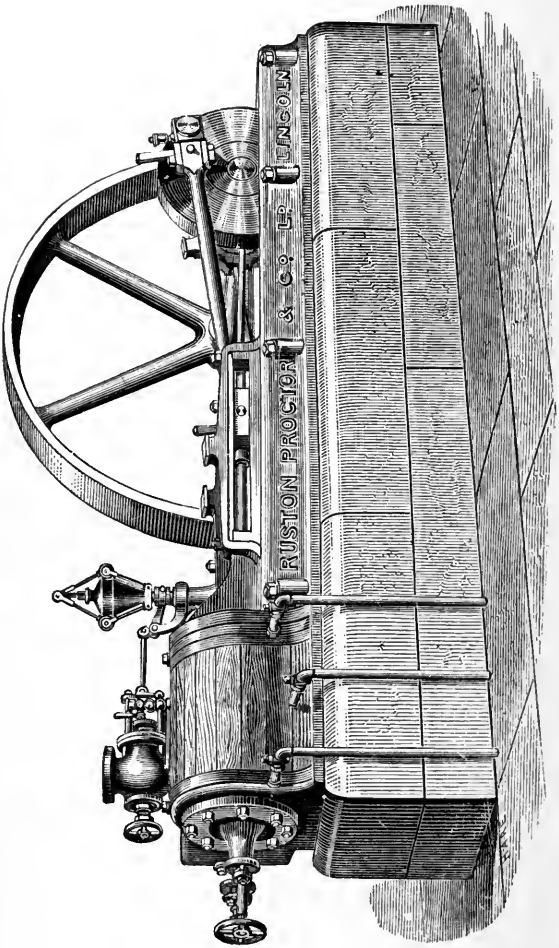



Fig. 938.

TABLE 111.—**Particulars of Messrs. Ruston & Proctor's Long-Stroke Horizontal Engines** (Fig. 938).

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinder | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 26 | 27 |
| Length of stroke . . | 16 | 16 | 20 | 20 | 24 | 24 | 28 | 28 | 32 | 32 | 36 | 36 | 40 | 40 | 44 | 44 | 52 | 52 |
| Revs. per minute . | 135 | 135 | 110 | 110 | 90 | 90 | 80 | 80 | 70 | 70 | 65 | 65 | 60 | 60 | 60 | 60 | 60 | 60 |
| Boiler press., lbs. per square inch | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Best average H.P. . | 15 | 20 | 25 | 30 | 35 | 40 | 48 | 55 | 65 | 75 | 85 | 95 | 110 | 120 | 140 | 160 | 230 | 250 |
| Diam. of fly-wheel . | 62 | 66 | 85 | 87 | 99 | 101 | 116 | 116 | 120 | 120 | 144 | 144 | 146 | 146 | 168 | 168 | 177 | 177 |
| Width of fly-wheel . | 7 | 9 | 8 | 8 | 10 | 10 | 12 | 14 | 14 | 16 | 16 | 18 | 20 | 22 | 22 | 24 | 28 | 30 |
| Weight of fly-wheel, cwts. . . | 10 | 12½ | 21½ | 21½ | 29½ | 29½ | 48 | 54 | 66 | 74 | 89½ | 105 | 130 | — | — | — | — | — |
| Diam. of crank-shaft | 3 | 3 | 3¾ | 3¾ | 4½ | 4½ | 5¼ | 5¼ | 6 | 6 | 6¾ | 6¾ | 7½ | 7½ | 8¼ | 8¼ | 9¾ | 9¾ |
| Total length . . | 142 | 142 | 160 | 160 | 188 | 188 | 218 | 218 | 240 | 240 | 274 | 274 | 294 | 294 | 335 | 335 | 378 | 378 |
| Total width . . | 75 | 75 | 84 | 84 | 93 | 93 | 102 | 102 | 114 | 114 | 123 | 123 | 132 | 132 | 141 | 141 | 150 | 150 |
| Approx. weight, cwts. | 48 | 50 | 76 | 80 | 106 | 112 | 156 | 162 | 204 | 214 | 310 | 323 | 338 | 358 | 473 | 493 | 700 | 720 |
| Height to centre . . | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |

All Dimensions are given in Inches.

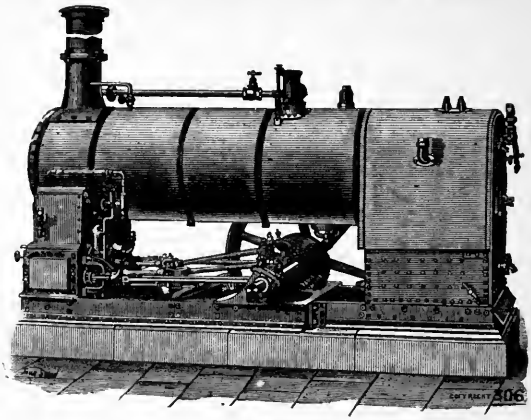


Fig. 939.

TABLE 112.—**Particulars of Compound Under-type Engines by Messrs. E. R. & F. Turner** (Fig. 939).

| | | | | |
|---|---|---|---|---|
| Diameter of small cylinder | 7 | 8 | 9 | 10 |
| Diameter of large cylinder | 11¼ | 12¾ | 14 | 16 |
| Length of stroke | 12 | 14 | 16 | 18 |
| Revolutions per minute | 180 | 155 | 135 | 120 |
| Piston speed in feet per minute | 360 | 360 | 360 | 360 |
| Best average indicated horse-power | 38 | 50 | 63 | 78 |
| Diameter of crank-shaft | 3½ | 3¾ | 4¼ | 5 |
| Diameter of fly-wheel | 60 | 72 | 72 | 84 |
| Width of fly-wheel | 8 | 9 | 10½ | 12 |
| Weight of fly-wheel, cwt. | 8 | 13 | 16 | 22 |
| Height to centre of boiler | 42½ | 49 | 58 | 66¼ |
| Height to centre of crank-shaft | 13 | 14½ | 17 | 19⅝ |
| Diameter of boiler-barrel | 34½ | 36¾ | 40½ | 47 |
| Length of boiler-barrel | 112 | 121½ | 132 | 142 |
| Heating-surface in square feet | 187·5 | 250 | 312·8 | 390 |
| Area of fire-grate in square feet | 5·06 | 6·6 | 8·2 | 10·25 |
| Width over all | 86 | 91 | 102 | 116 |
| Working pressure in lbs. per sq. in. | 140 | 140 | 140 | 140 |

All Dimensions in Inches.

N.B.—The heating-surfaces and boiler dimensions in the table are given for ordinary English coal; for inferior and colonial coal, about 25 per cent. should be added to grate area and fire-box heating surface.

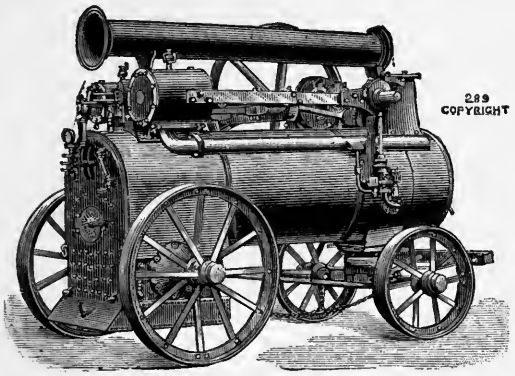



Fig. 940.

**Table 113.—Particulars of Compound Portable Engines by Messrs. E. R. & F. Turner** (Fig. 940).

| | | | |
|---|---|---|---|
| Diameter of small cylinder . . | 7 | 8 | 9 |
| Diameter of large cylinder . . . | 11¼ | 12¾ | 14 |
| Length of stroke . . . . . | 12 | 14 | 16 |
| Revolutions per minute . . . | 180 | 155 | 135 |
| Piston speed in feet per minute . | 360 | 360 | 360 |
| Best average indicated horse-power . | 36 | 48 | 60 |
| Diameter of crank-shaft . . . | 3¾ | 3¾ | 4¼ |
| Diameter of fly-wheel . . . . | 60 | 72 | 72 |
| Width of fly-wheel . . . . . | 8 | 9 | 10½ |
| Weight of fly-wheel in cwt. . . . | 8 | 13 | 16 |
| Diameter of boiler-barrel . . . | 34½ | 36¾ | 40½ |
| Length of boiler over all . . . | 147 | 161½ | 179 |
| Heating-surface in square feet . . | 187·5 | 250 | 312·8 |
| Area of grate in square feet . . . | 5·06 | 6·6 | 8·2 |
| Length over all . . . . . | 158 | 173 | 192 |
| Width over axles . . . . . | 87 | 89 | 93 |
| Height to top of boiler . . . | 109 | 118 | 126 |
| Working-pressure in lbs. per sq. in. . | 140 | 140 | 140 |

Dimensions in Inches.

See remarks as to heating-surface in Table 112.

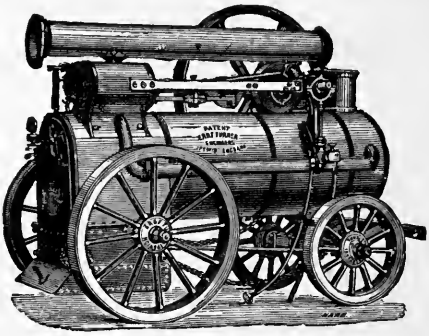


Fig. 941.

TABLE 114.—**Particulars of Single-Cylinder Portable Engines by Messrs. E. R. & F. Turner** (Fig. 941).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Diameter of cylinder. | 6 | 6¾ | 7½ | 8½ | 9 | 9½ | 10½ |
| Length of stroke . . | 9 | 10½ | 10½ | 12 | 12 | 12 | 12 |
| Revs. per minute . | 180 | 150 | 150 | 130 | 130 | 130 | 130 |
| Piston speed in feet per minute . . | 270 | 263 | 263 | 260 | 260 | 260 | 260 |
| Best aver. indic. H.P. | 6 | 8 | 10 | 12 | 14 | 16 | 20 |
| Diam. of crank-shaft . | 2⅛ | 2⅜ | 2½ | 2¾ | 3 | 3 | 3¼ |
| Diam. of fly-wheel . | 45 | 52 | 52 | 60 | 60 | 60 | 60 |
| Width of fly-wheel . | 4½ | 5 | 5 | 6 | 6 | 6 | 7 |
| Weight of do. cwt. | 3 | 3½ | 3½ | 6½ | 6¾ | 6¾ | 7½ |
| Diam. of boiler-barrel | 24 | 29 | 29 | 30⅜ | 33½ | 33½ | 34½ |
| Length of do. . . | 62 | 67 | 81 | 83 | 80⅝ | 85⅜ | 95¼ |
| Heating-surface, sq. ft. | 59·4 | 78·36 | 96·37 | 109·03 | 128 | 144·27 | 172·29 |
| Area of fire-grate, sq. ft. | 2·02 | 2·38 | 2·96 | 3·27 | 3·61 | 4·12 | 5·01 |
| Approx. weight, cwt. | 40 | 50 | 57 | 65 | 74 | 82 | 95 |
| Length over all . . | 96 | 112 | 120 | 126 | 126 | 132 | 138 |
| Width over axles . . | 58 | 66 | 66 | 73 | 77 | 79 | 82 |
| Height to top fly-wheel | 75 | 93 | 93 | 99 | 104 | 106 | 110 |
| Working-pressure in lbs. per sq. inch . | 80 | 80 | 80 | 80 | 80 | 80 | 80 |

Dimensions in Inches.

See remarks as to heating-surface, &c., in Table 112.

Portable engines have been and are still manufactured in large numbers in England, and have settled down into few varieties. In the first portable engines, pressures were low and there was no objection to throwing the whole strain of the working on to the barrel plates of the boiler. Now, however, with higher pressures the tendency has been to relieve the boiler as much as possible of the working strain due to the pressure of steam on the piston, by adding stay bars between the cylinder and the crank shaft bearings, or in some cases of mounting the engine on a frame of its own which is then bolted to stools rivetted on the boiler ; this would seem to commend itself on account of the facilities of packing for export, and facility of carriage up difficult countries.

From the portable engine the road locomotive or traction engine has been developed, and the number of these for farm purposes increases every year ; they do not differ greatly from the portable engine as far as the engine itself is concerned, but have the addition of gearing and travelling wheels of various designs.

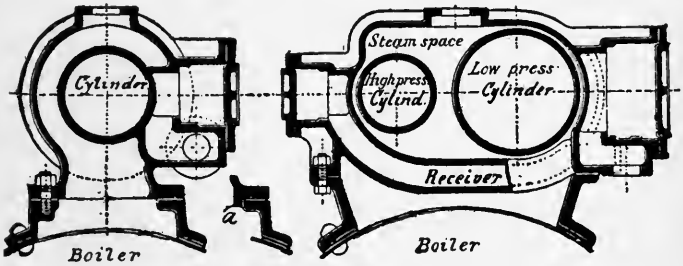



Fig. 941A.

Compound portable engines have come into favour for the larger sizes ; the cylinders of these are usually arranged side by side, Fig. 941A, and the cranks at right angles, the receiver taking the form of a pipe under the cylinders and concealed in the casing so that the receiver has the advantage of being well protected from cold air, and from its position close to the boiler top is kept in a hot atmosphere. The steam pipe in portable engines is reduced to a minimum in length and the steam jacket can be readily drained direct into the boiler ; these are great advantages and no doubt contribute to the very economical results which are obtained from portable engines.

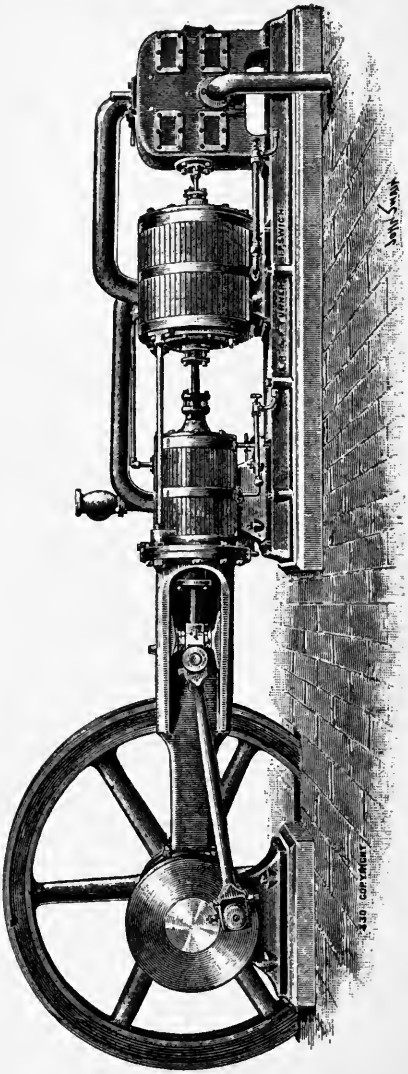


Fig. 942.

TABLE 115.—**Particulars of Tandem Compound Engines by Messrs. E R. & F. Turner** (Fig. 942).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Best average indicated H.P. | 44 | 55 | 68 | 82 | 96 | 110 | 124 | 140 |
| Diameter of small cylinder | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Diameter of large cylinder | 14 | 16 | 18 | 20 | 21 | 23 | 25 | 26 |
| Length of stroke | 16 | 20 | 20 | 24 | 24 | 28 | 28 | 36 |
| Revolutions per minute | 150 | 120 | 120 | 100 | 100 | 86 | 86 | 70 |
| Diameter of fly-wheel | 84 | 96 | 96 | 114 | 114 | 129 | 129 | 144 |
| Width of fly-wheel | 8 | 9 | 9 | 11 | 11 | 12 | 12 | 14 |
| Weight of fly-wheel in cwts. | 30 | 50 | 50 | 62 | 62 | 80 | 80 | 100 |
| Diameter of crank-shaft at journal | $4\frac{1}{4}$ | 5 | 5 | 6 | 6 | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{2}$ |
| Diameter of crank-shaft at fly-wheel | $5\frac{1}{2}$ | $6\frac{3}{8}$ | $6\frac{3}{8}$ | $7\frac{1}{2}$ | $7\frac{1}{2}$ | $8\frac{1}{4}$ | $8\frac{1}{4}$ | $9\frac{1}{2}$ |
| Height of centre from ground | 28 | 30 | 30 | 32 | 32 | 34 | 34 | 36 |

Dimensions are given in Inches.

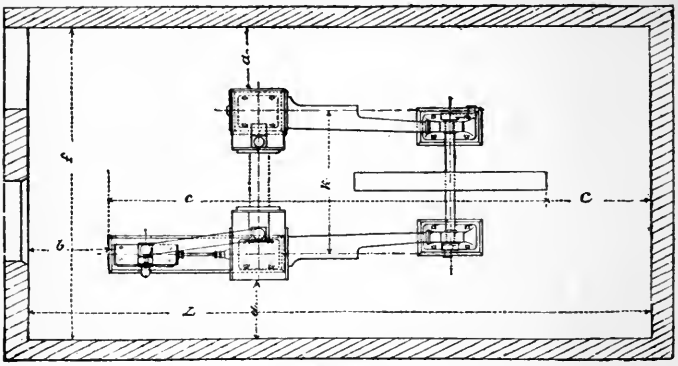



Fig. 943.

TABLE 116.—**Particulars of Floor-Space occupied by Coupled Compound Condensing Engines by Messrs. E. R. & F. Turner** (Fig. 943).

| | | 9 & 14 | 10 & 16 | 11 & 18 | 12 & 20 | 13 & 21 | 14 & 23 | 15 & 25 | 16 & 26 |
|---|---|---|---|---|---|---|---|---|---|
| Diameter of cylinders . . | | | | | | | | | |
| Length of stroke . . | | 16 | 20 | 20 | 24 | 24 | 28 | 28 | 36 |
| Distance from cyls. to wall | *a* | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| „ „ „ | *b* | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| „ „ „ | *c* | 12 | 12 | 12 | 18 | 18 | 18 | 18 | 18 |
| Total length of engine | C | — | 201 | 201 | 237 | 237 | 272 | 272 | 342 |
| Total width of engine room | *f* | 173 | 176 | 176 | 188 | 190 | 199 | 202 | 210 |
| Distance between centres of cylinders . . | K | 78 | 78 | 78 | 84 | 84 | 90 | 90 | 96 |
| Total length of engine room . . . . | L | — | 249 | 249 | 285 | 285 | 320 | 320 | 390 |

Dimensions are given in Inches.

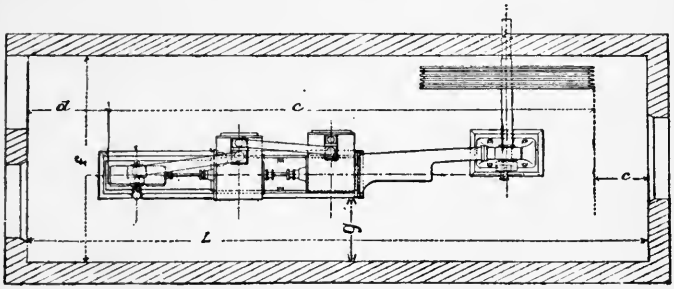



Fig. 944.

TABLE 117.—**Particulars of Floor-Space Occupied by Tandem Compound Condensing Engines by Messrs. E. R. & F. Turner** (Fig. 944).

| | 9 & 14 | 10 & 16 | 11 & 18 | 12 & 20 | 13 & 21 | 14 & 23 | 15 & 25 | 16 & 26 |
|---|---|---|---|---|---|---|---|---|
| Diameter of cylinders . . | | | | | | | | |
| Stroke of piston . . . | 16 | 20 | 20 | 24 | 24 | 28 | 28 | 36 |
| Total length of engine-room L | — | 327 | 327 | 381 | 381 | — | — | — |
| Total width of engine-room F | — | 107 | 107 | 121 | 121 | — | — | — |
| Distance from engine to wall *c* | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| „ „ „ *d* | 36 | 36 | 36 | 42 | 42 | 42 | 42 | 48 |
| „ „ „ *g* | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Length over all of engine C | — | 276 | 276 | 324 | 324 | — | — | — |

Dimensions are given in Inches.

TABLE 118.—**Particulars of Compound Coupled Condensing Engines by Messrs. E. R. & F. Turner** (see also Table 116).

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Best average indicated H.P. | 44 | 55 | 68 | 82 | 96 | 110 | 124 | 140 |
| Diameter of small cylinder | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Diameter of large cylinder | 14 | 16 | 18 | 20 | 21 | 23 | 25 | 26 |
| Length of stroke | 16 | 20 | 20 | 24 | 24 | 28 | 28 | 36 |
| Revolutions per minute | 150 | 120 | 120 | 100 | 100 | 86 | 86 | 70 |
| Diameter of fly-wheel | 84 | 96 | 96 | 114 | 114 | 129 | 129 | 144 |
| Width of fly-wheel | 8 | 9 | 9 | 11 | 11 | 12 | 12 | 14 |
| Weight of fly-wheel in cwts. | 25 | 40 | 40 | 50 | 50 | 64 | 64 | 80 |
| Height of centre from ground | 24 | 24 | 24 | 26 | 26 | 27 | 27 | 33 |
| Diameter of crank-shaft at journal | $3\frac{1}{4}$ | $3\frac{3}{4}$ | $3\frac{3}{4}$ | $4\frac{1}{4}$ | $4\frac{1}{4}$ | 5 | 5 | 6 |
| Diameter of crank-shaft at fly-wheel | $4\frac{1}{4}$ | $4\frac{3}{4}$ | $4\frac{3}{4}$ | $5\frac{3}{4}$ | $5\frac{3}{4}$ | $6\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{2}$ |

Dimensions are given in Inches.

Fig. 945

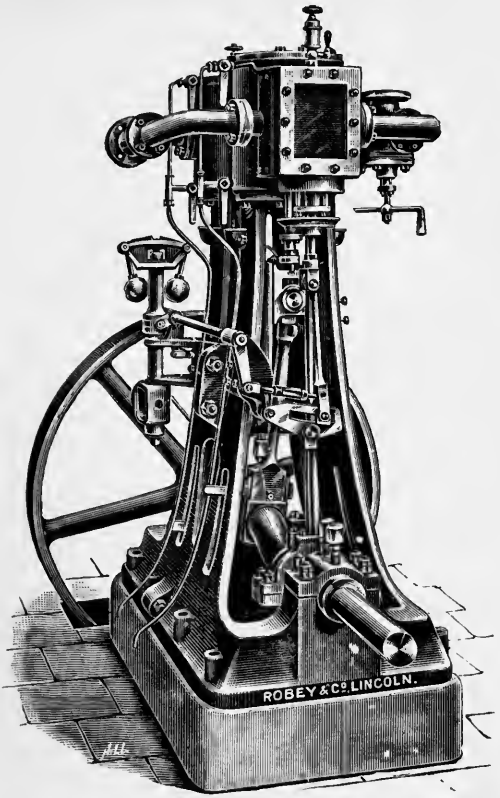



TABLE 119.—**Particulars of a Double Cylinder Vertical Engine* by Messrs. Robey & Co.** (Fig. 945).

| | | | |
|---|---|---|---|
| Nominal horse-power . | 16 | Width of fly-wheel . . | 11 |
| Diameter of cylinders, each | 9½ | Height to centre of crank from under side of standard . . . | 11 |
| Length of stroke . . | 12 | | |
| Revolutions per minute . | 150 | Total height . . . | 79 |
| Best average B.H.P. . . | 32 | „ width . . . . | 60 |
| Diameter of crank-shaft . | 4 | „ length . . . | 80 |
| Diameter of fly-wheel . . | 60 | Approx. weight in cwt. . | 54 |
| Weight of fly-wheel, cwt. . | 15 | | |

* For 80 lbs. boiler pressure. Dimensions are given in Inches.

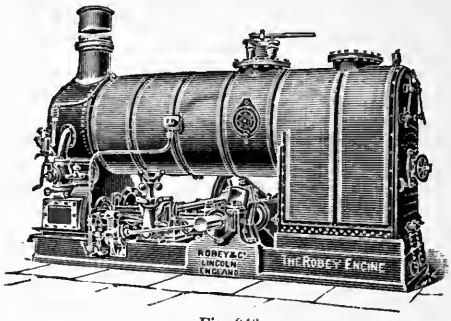



Fig. 946.

TABLE 120.—**Particulars of Compound Undertype Engines by Messrs. Robey & Co.** (Fig. 946).

| Nominal H.P. | 8 | 50 |
|---|---|---|
| Diameter of H.P. cylinder | $5\frac{1}{2}$ | $13\frac{1}{4}$ |
| Diameter of L.P. cylinder | $9\frac{1}{2}$ | 23 |
| Length of stroke | 12 | 24 |
| Revolutions per minute | 200 | 100 |
| Best average I.H.P. | 24 | 150 |
| Diameter of crank-shaft | $3\frac{1}{4}$ | 8 |
| Diameter of fly-wheel | 58 | 96 |
| Width of fly-wheel | $7\frac{1}{2}$ | 23 |
| Weight of fly-wheel in cwts. | $8\frac{1}{4}$ | 96 |
| Height to centre of boiler | 46 | $94\frac{1}{2}$ |
| Height to centre of engine | $15\frac{1}{2}$ | $33\frac{1}{2}$ |
| Diameter of boiler | $31\frac{3}{8}$ | 61 |
| Length of boiler | 128 | 231 |
| Heating-surface in square feet | 169·4 | 757·7 |
| Grate area in square feet | 5·8 | 21·8 |
| Width over all | 63 | 126 |
| Approx. weight, cwts. | 50 | 380 |
| Boiler-pressure | 140 | 140 |

Dimensions are given in Inches.

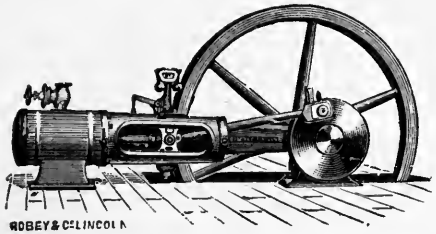



Fig. 947.

TABLE 121.—**Particulars of Horizontal Girder Engines by Messrs. Robey & Co.** (Fig. 947).

| Nominal H.P. | 8 | 30 |
|---|---|---|
| Diameter of cylinder | 9 | 18 |
| Length of stroke | 18 | 36 |
| Revolutions per minute | 133 | 84 |
| Best average I.H.P. | 28 | 142 |
| Diameter of crank-shaft | 4 | 8 |
| Diameter of fly-wheel | 66 | 144 |
| Width of fly-wheel | 8 | 17 |
| Weight of fly-wheel, cwts. | 18 | 90 |
| Height to centre of cylinder | 15 | 28 |
| Total length over all | 125 | 247 |
| Total width over all | 65 | 134 |
| Total weight, approx. in cwts. | 48 | 270 |
| Boiler-pressure | 80 | 80 |

Dimensions are given in Inches.

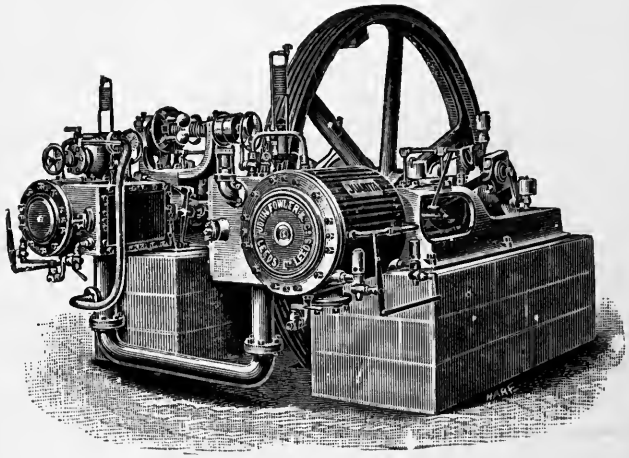


Fig. 948.

TABLE 122.—**Particulars of Compound Coupled Non-condensing Engine by Messrs. John Fowler & Co.**

| | | | | | |
|---|---|---|---|---|---|
| Diameter of high pressure cylinder . . . . | 10 | 11 | 13 | 15 | $17\frac{1}{2}$ |
| Diameter of low pressure cylinder . . . . | 16 | $17\frac{1}{2}$ | 23 | 24 | $27\frac{1}{2}$ |
| Length of stroke . . | 20 | 20 | 24 | 30 | 36 |

**Dimensions are given in Inches.**

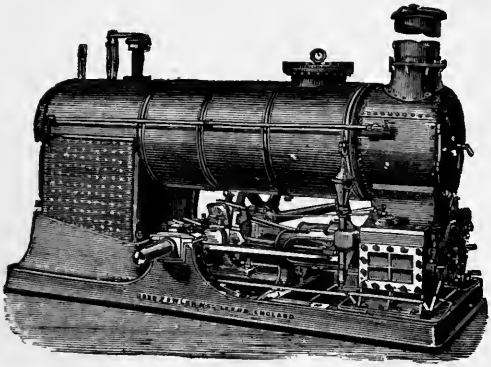


Fig. 949.

TABLE 123.—**Particulars of Compound Undertype Engines by Messrs. John Fowler & Co.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of high pressure cylinder . . | $5\frac{3}{4}$ | $6\frac{5}{8}$ | $7\frac{1}{4}$ | 8 | 9 | 10 | 11 | 12 | 13 | 17 | 18 |
| Diameter of low pressure cylinder . . | 9 | $10\frac{1}{2}$ | $11\frac{1}{4}$ | $12\frac{3}{4}$ | 14 | 16 | $17\frac{1}{2}$ | 21 | 23 | 27 | 29 |
| Length of stroke . | 12 | 14 | 14 | 15 | 16 | 18 | 18 | 24 | 24 | 30 | 30 |

Dimensions are given in Inches.

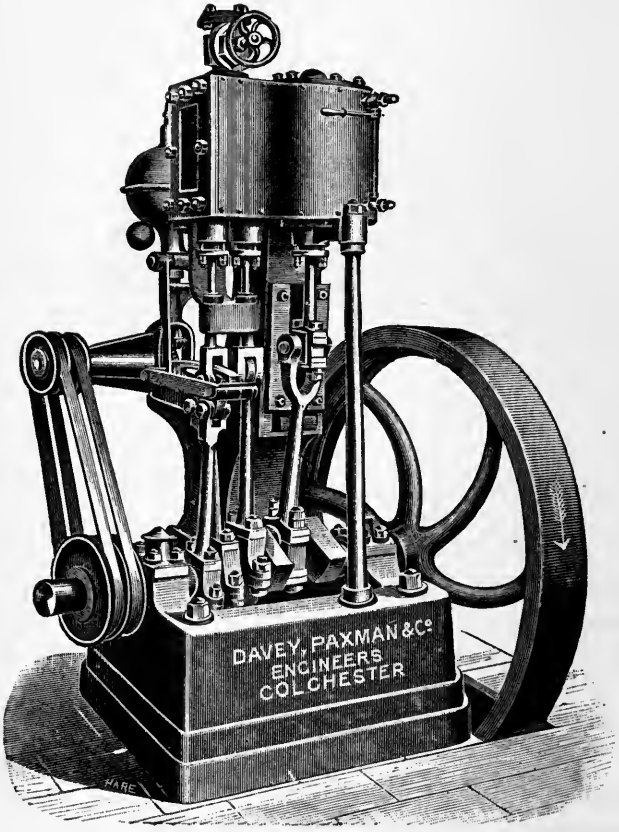



Fig 950.

**TABLE 124.—Single Cylinder Vertical Engines** (Fig. 950) **by Davey, Paxman & Co.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal H.P. . . | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
| Diameter of cylinder . . | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{4}$ | $8\frac{1}{4}$ | $9\frac{1}{2}$ | $10\frac{1}{2}$ | 12 |
| Length of stroke . . | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 12 |
| Revolutions per minute { | 300 | 260 | 260 | 225 | 225 | 200 | 180 | 160 |
| | 400 | 350 | 350 | 300 | 300 | 260 | 250 | 220 |
| Best average I.H.P. . . | 5 | $7\frac{1}{2}$ | 10 | $12\frac{1}{2}$ | 15 | 20 | 25 | 30 |
| Diameter of fly-wheel . | 42 | 42 | 42 | 48 | 48 | 48 | 54 | 54 |
| Width of fly-wheel . . | $3\frac{1}{2}$ | 4 | 5 | 5 | 6 | 7 | 8 | 8 |

**TABLE 125.—Double Cylinder Vertical Engines by Davey, Paxman & Co.**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal H.P. . . | 4 | 6 | 8 | 10 | 12 | 16 | 20 | 25 |
| Diameter of cylinders. . | $4\frac{1}{2}$ | $5\frac{1}{2}$ | $6\frac{1}{2}$ | $7\frac{1}{4}$ | $8\frac{1}{4}$ | $9\frac{1}{2}$ | $10\frac{1}{2}$ | 12 |
| Length of stroke . . | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 12 |
| Revolutions per minute { | 300 | 260 | 260 | 225 | 225 | 200 | 180 | 160 |
| | 400 | 350 | 350 | 300 | 300 | 260 | 250 | 220 |
| Best average I.H.P. . . | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 62 |
| Diameter of fly-wheel . | 42 | 42 | 42 | 48 | 48 | 48 | 54 | 60 |
| Width of fly-wheel . . | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

All Dimensions are given in Inches.

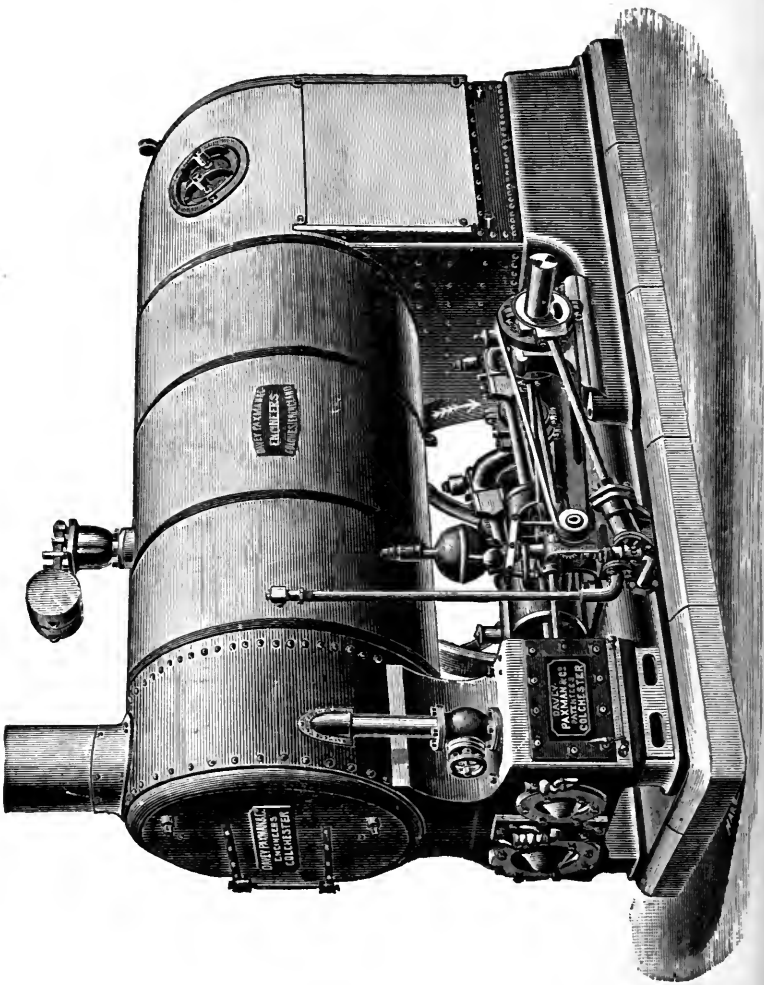



Fig 951.

## Undertype Engines by Messrs. Davey, Paxman & Co.

TABLE 126.—**Compound Engines** (Fig. 951).

| Nominal H.P. | 8 | 10 | 12 | 16 | 20 | 25 | 30 | 35 | 40 | 50 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of high pressure cylinder | 5½ | 6½ | 7 | 8 | 9 | 10 | 11 | 12 | 12¾ | 14 | 16 |
| Diameter of low pressure cylinder | 9 | 10½ | 11¼ | 13 | 14¼ | 16 | 17½ | 18¾ | 20 | 22½ | 25 |
| Length of stroke | 14 | 14 | 14 | 14 | 14 | 18 | 18 | 24 | 24 | 24 | 24 |
| Revolutions per minute | 155 | 155 | 155 | 155 | 155 | 120 | 120 | 90 | 90 | 90 | 90 |
| Best average I.H.P. | 20 | 25 | 30 | 40 | 50 | 62 | 75 | 80 | 100 | 125 | 150 |
| Diameter of fly-wheel | 60 | 60 | 60 | 66 | 66 | 84 | 84 | 102 | 102 | 102 | 102 |
| Width of fly-wheel | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 | 17 | 20 | 22 |

TABLE 127.—**Single Cylinder.**

| Nominal H.P. | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|
| Diameter of cylinder | 6½ | 7¼ | 8¼ | 9½ | 10½ | 12 |
| Length of stroke | 12 | 12 | 12 | 12 | 14 | 14 |
| Revolutions per minute | 125 | 125 | 125 | 125 | 115 | 115 |
| Best average I.H.P. | 6 | 12½ | 15 | 20 | 25 | 30 |
| Diameter of fly-wheel | 52 | 60 | 60 | 60 | 66 | 66 |
| Width of fly-wheel | 5 | 5 | 6 | 7 | 8 | 9 |

**All Dimensions are given in Inches.**

TABLE 128.—**Willans' Central Valve Engines (Non-Condensing Type).**

| Mark | F | F | G | G | H | H | I | I |
|---|---|---|---|---|---|---|---|---|
| Number of cranks | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Diameter of low pressure cylinders | 12″ | 12″ | 14″ | 14″ | 17″ | 17″ | 20″ | 20″ |
| Stroke | 6″ | 6″ | 6″ | 6″ | 8″ | 8″ | 9″ | 9″ |
| Speed, revolutions per minute | 470 | 470 | 460 | 460 | 380 | 380 | 350 | 350 |
| Maximum load for continuous running, I.H.P. | 75 | 112 | 100 | 150 | 165 | 250 | 240 | 360 |
| Boiler pressure, simple engines | — | — | — | — | 100 | — | — | — |
| ,, compound engines | — | — | — | — | 140 | — | — | — |
| ,, triple expansion engines | — | — | — | — | 190 | — | — | — |

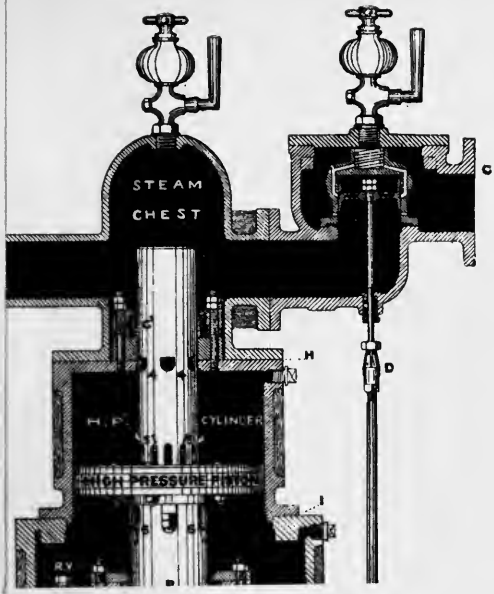

STEAM
CHEST
C
H
D
H.P.
CYLINDER
HIGH PRESSURE
I
RV

TABLE 129.—**Willans' Central Valve Engines (Condensing Type).**

| Mark | O | O | B | B | P | P | Q | Q | R | R | S | S | T | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cranks | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 2 | 3 |
| Diameter of low pressure cylinders | 17·32 | | 20·47 | | 23·6 | | 25·6 | | 28·3 | | 30·4 | | 32·3 | |
| Stroke | 5·9 | | 6·89 | | 7·88 | | 9·05 | | 10·24 | | 11·4 | | 13·39 | |
| Speed, revolutions per minute | 450 | | 400 | | 360 | | 340 | | 320 | | 300 | | 270 | |
| Maximum load for continuous running | 120 | 180 | 180 | 270 | 240 | 360 | 300 | 450 | 385 | 575 | 470 | 705 | 550 | 825 |

| Mark | V | V L | V S | V L | W S | W L | X S | X L | Y S | Y L | Z S | Z L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cranks | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Diameter of low pressure cylinders | 37·5 | | 37·5 | | 43·3 | | 48 | | 53 | | 67 | |
| Stroke | 16·9 | 22·4 | 16·9 | 22·4 | 20·47 | 27·6 | 23·6 | 31·5 | 28·3 | 37·8 | 33·5 | 44·5 |
| Speed, revolutions per minute | 240 | 180 | 240 | 180 | 220 | 165 | 200 | 150 | 180 | 135 | 160 | 120 |
| Maximum load for continuous running | 835 | 835 | 1250 | | 1875 | | 2500 | | 3750 | | 5000 | |

Boiler pressure, not less than 75 lbs. for simple engines, 110 lbs for compound engines, and 160 lbs. for triple expansion engines.

Quick-running enclosed engines are now very much in use for driving electric light and power machinery, the dynamos being usually coupled direct on to the engine shaft. There are two distinct types of these engines: single acting, of which Willans' central valve

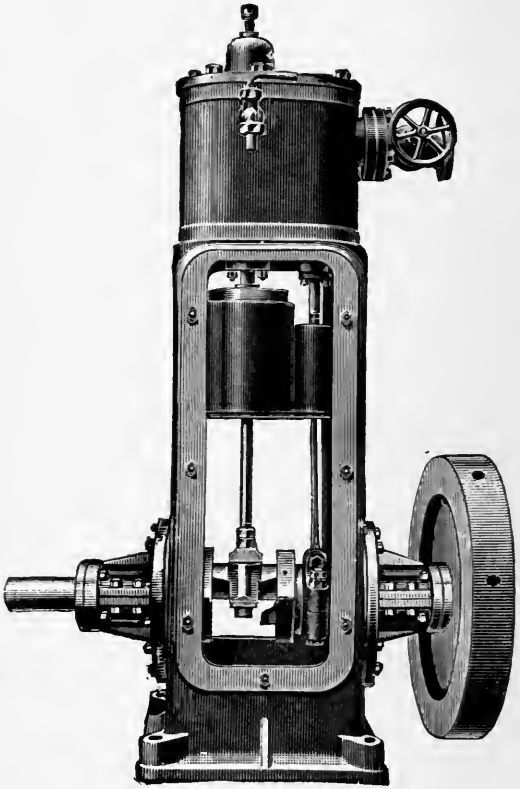


Fig. 952A.

engine may be taken as typical, and double-acting engines, of which that of Messrs. Belliss may be taken as typical.

The engine of Messrs. Willans, of the Victoria Works, Rugby, is shown in fig. 952, the cycle through which the steam goes being the same as in the old Cornish pumping engines; tables of sizes and speeds are given on pages 348 and 349.

Another example of the single-acting type is shown in fig. 952A, and is made by Messrs. Bumsted & Chandler, of Hednesford, Staffordshire. In fig. 952A the doors which enclose the engine are removed to show the arrangement; the piston and valve rods work through ordinary stuffing-boxes; these latter never being subjected to the full pressure of the steam from the boiler, each cylinder receiving but one charge of steam per revolution, the piston and valve rod stuffing-boxes at the lower end of the cylinder are subjected to exhaust pressure only; this should render the packing more durable than when subjected to steam of high pressure and temperature. By a new improvement the crank shaft brasses can be readily taken out for examination, and the crank shaft can be drawn out from either side of the engine. It is a special feature of all single-acting engines that they can be run at a very high speed with but little noise, owing to all working parts being always in compression, the strain never being reversed.

Of the double-acting type the engine of Messrs. Belliss & Morcomb Ltd., Birmingham, has proved very successful. Messrs. Belliss claim to have introduced their system of forced lubrication in 1890, and very efficient this system has proved to be. Fig. 952C shows the arrangement and construction of the engine, and the system of forced lubrication. The governing of this engine is very good, and even under the severe and sudden changes in load which occur in engines used for driving dynamos for electric traction, the variation in speed is very slight. The forced lubrication is essential to quick-running engines, and the wear and tear in engines of this kind is very small.

The distribution of steam in the double-acting engines is slightly more economical than in the single-acting Cornish cycle engine, but the difference in practice is small.

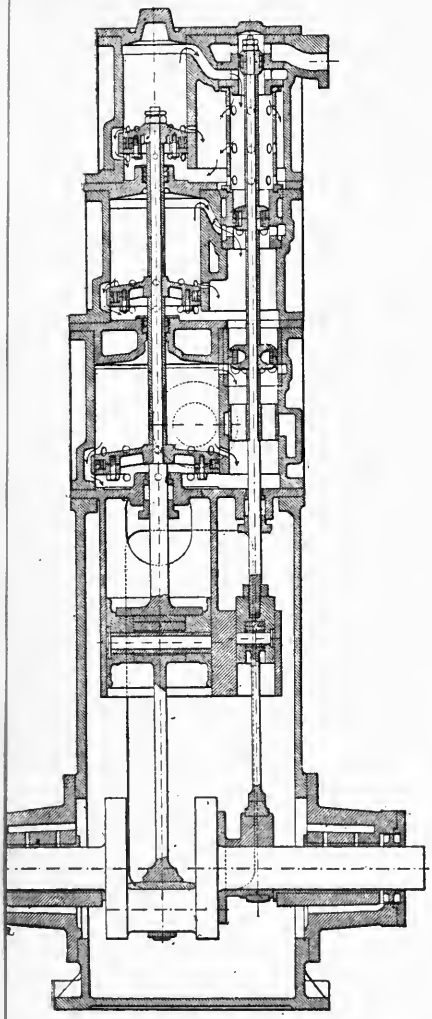
The large number of these enclosed engines now in use, and the long runs they are daily making without requiring adjustment, point rather to the fact that engines, when properly constructed and lubricated, require but little attention, and when enclosed and thus kept out of the way, run very much better than open engines, where adjustment is so easy that it is often done when not required.

TABLE 129A.—**Particulars of Chandler's "Silent" Engines** (Fig. 952A).
**Single-Crank Engines.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of low-pressure cylinder . . | 3 | 5 | 5¾ | 6½ | 8 | 9½ | 11 | 13 | 15 | 18 | 20 | 24 | * |
| Revolutions per minute . . . . . | 800 | 625 | 600 | 550 | 500 | 450 | 425 | 400 | 380 | 350 | 350 | 225 | |
| Available brake horse power when exhausting into atmosphere at the following boiler pressures :— | | | | | | | | | | | | | |
| 60 lbs. per square inch . . . | ¾ | 3 | 4 | 5 | 8 | 11 | 17 | 24 | 32 | 48 | 60 | 98 | S |
| 80 „ „ . . . | 1 | 4 | 6 | 7 | 11 | 16 | 22½ | 32 | 43 | 64 | 80 | 131 | S |
| 90 „ „ . . . | 1¼ | 5 | 7 | 9 | 14 | 19 | 28 | 40 | 54 | 80 | 100 | 163 | S |
| 100 „ „ . . . | | | 5 | 6½ | 10½ | 14 | 21 | 30 | 40 | 60 | 75 | 123 | C |
| 125 „ „ . . . | | | 7 | 9 | 14 | 19 | 28 | 40 | 54 | 80 | 100 | 163 | C |
| 150 „ „ . . . | | | 8 | 10 | 16 | 22 | 33 | 48 | 64 | 96 | 120 | 195 | C |
| 160 „ „ . . . | | | | | | 19 | 28 | 40 | 54 | 80 | 100 | 163 | T |

The diameter of the fly-wheel of these engines is three times the diameter of the low-pressure cylinder, and the width of the fly-wheel is ·5 of the diameter of the low-pressure cylinder.

* S means simple; C, compound; T, triple expansion. All Dimensions are given in Inches.



ed and Chandler.

[*To face p.* 352.

TABLE 129B.—**Particulars of Chandler's "Silent" Engines.**
**Double-Crank Engines.**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of low-pressure cylinder . . | 3 | 5 | 5¾ | 6½ | 8 | 9½ | 11 | 13 | 15 | 18 | 20 | 24 | * |
| Revolutions per minute . . . . . | 800 | 625 | 600 | 550 | 500 | 450 | 425 | 400 | 380 | 350 | 350 | 225 | |
| Available brake horse power (when exhausting into atmosphere) at the following boiler pressures :— | | | | | | | | | | | | | |
| 60 lbs. per square inch . . . | 1½ | 6 | 8 | 10 | 16 | 22 | 34 | 48 | 64 | 96 | 120 | 196 | S |
| 80 „ „ . . . | 2 | 8 | 12 | 14 | 22 | 32 | 45 | 64 | 86 | 128 | 160 | 262 | S |
| 90 „ „ . . . | 2½ | 10 | 14 | 18 | 28 | 38 | 56 | 80 | 108 | 160 | 200 | 326 | S |
| 100 „ „ . . . | | | 10 | 13 | 21 | 28 | 42 | 60 | 81 | 120 | 150 | 240 | C |
| 125 „ „ . . . | | | 14 | 18 | 28 | 38 | 56 | 80 | 108 | 160 | 200 | 326 | C |
| 150 „ „ . . . | | | 16 | 20 | 32 | 44 | 66 | 96 | 128 | 192 | 240 | 390 | C |
| 160 „ „ . . . | | | | | | 38 | 56 | 80 | 108 | 164 | 200 | 320 | T |

Diameter and width of fly-wheel as in Table 129A.

The indicated H.P. of these engines is from 5 to 10 per cent. higher than the brake H.P. given in the tables according to the size of the engines. When exhausting into a condenser the powers will be about 10 per cent. higher than those given in the tables.

A A

* S, simple ; C, compound ; T, triple expansion. All Dimensions are given in Inches.

TABLE 129c.—**Belliss & Morcom's Quick Revolution Engines.**

**Compound, Non-Condensing.**

| Mark | C 1 | C 2 | C 3 | C 4 | C 5 | C 6 | C 7 | C 8 | C 9 | C 10 | C 11 | C 12 | C 13 | C 14 | C 15 | C 16 | C 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cranks | 2 | | | | | | | | | | | | | | | | |
| Speed, revolutions per minute | 650 | 625 | 600 | 575 | 525 | 525 | 475 | 450 | 435 | 425 | 420 | 400 | 400 | 380 | 360 | 350 | 325 |
| Maximum brake H.P. approximate | 30 | 38 | 53 | 75 | 90 | 110 | 135 | 150 | 180 | 200 | 225 | 260 | 300 | 325 | 360 | 400 | 500 |

Boiler pressure, 140 lbs. to 150 lbs. per square inch.

**Triple Expansion.**

| Mark | T 1 | T 2 | T 3 | T 4 | T 5 | T 6 | T 7 | T 8 | T 9 | T 10 | T 11 | T 12 | T 13 | T 14 | T 15 | T 16 | T 17 | T 18 | T 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of cranks | 3 | | | | | | | | | | | | | | | | | | |
| Speed, revolutions per minute | 550 | 500 | 475 | 450 | 400 | 375 | 400 | 340 | 350 | 330 | 330 | 280 | 300 | 300 | 250 | 270 | 230 | 250 | 200 |
| Maximum brake H.P. approximate | 220 | 220 | 300 | 325 | 400 | 430 | 500 | 500 | 620 | 720 | 800 | 800 | 1100 | 1250 | 1300 | 1525 | 1585 | 2140 | 2140 |

Boiler pressure, 170 lbs. to 200 lbs. per square inch.

**Belliss & Morcom's Quick Revolution Self-Lubricating Engine.**

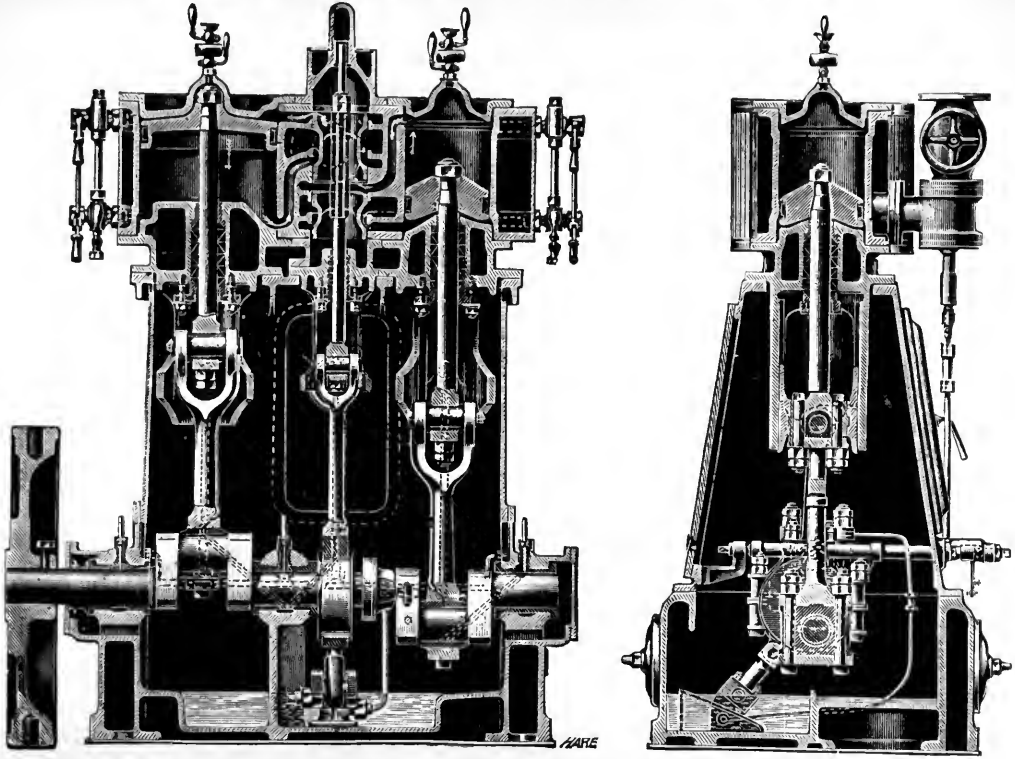



Fig. 952D.

## SECTION VIII.

### COMPOUND ENGINES.

THE early compound engines by Woolf had no intermediate receiver, and the passage of the steam was direct from the high to the low pressure cylinder. In some cases, as in figs. 953, 954, both pistons moved together in the same direction. A form of valve suitable for this kind of engine is shown in fig. 954, which also gives a section

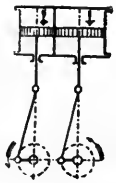


Fig. 953.

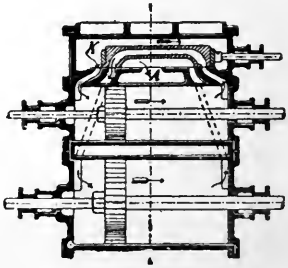



Fig. 954.

through the cylinders with arrows to indicate the course of the steam through the ports and passages. In this arrangement the passages

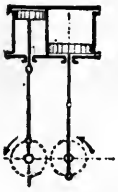


Fig. 955.

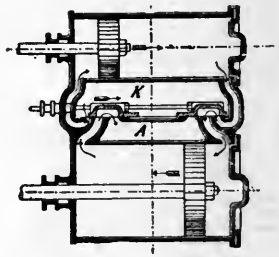



Fig. 956.

to the low pressure cylinder are long and thus give a large clearance space.

In the arrangement shewn in figs. 955, 956, the pistons move in

opposite directions. The clearance space here is less than in the former example, figs. 953, 954.

The indicator diagram, fig. 957, is from an arrangement like fig. 956, with cut-off at ·4 in the high, and at ·8 in the low pressure cylinder.

In these types of compound engines, it is a good plan to have the cut-off in the high pressure cylinder controlled by the governor, and

Fig. 957.

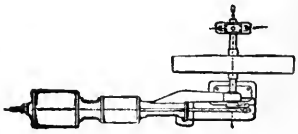


Fig. 958.

that of the low variable by hand. The side-by-side cylinders, with pistons moving together as fig. 954, have been much used for beam pumping engines.

## Tandem Compound Engine.

The tandem horizontal engines, as fig. 958, often have a receiver even if it only takes the form of a large connecting pipe. These engines take up but little room in the width, but are rather long.

Examples of the various methods of connecting the high and low pressure cylinders of tandem compound engines are shewn in figs. 959—963.

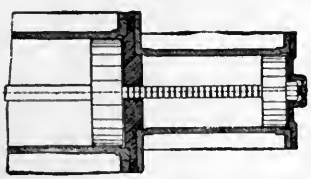


Fig. 959.—High and low-pressure cylinders for tandem engine by Simpson, of Dartmouth.*

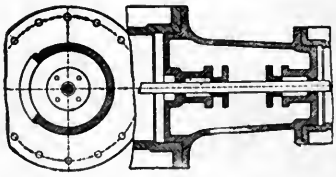


Fig. 960.—Connecting-piece for tandem cylinders used for vertical engines.

* For performance of a small engine of this type, see reports of judges of Royal Agricultural Society's meeting at Plymouth, 1890.

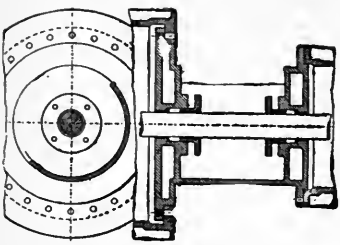


Fig. 961.

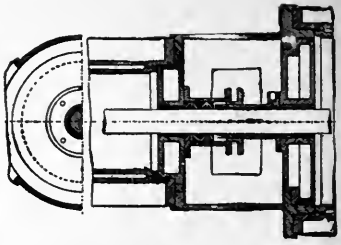


Fig. 962

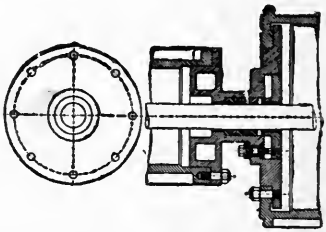


Fig. 963.

Figs. 961—963.—Various methods of arranging the connecting-piece and glands for tandem cylinder.

## Compound Engines with the Cranks at 90°.

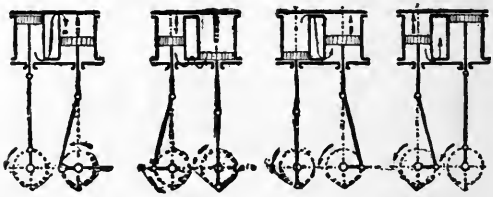


Fig. 964.

The outline diagrams, fig. 964, shew the different positions of cranks and pistons in a compound engine with two cranks at right angles to each other, and fig 965 shews the indicator diagrams corresponding to the two cylinders. H in fig 965 gives the position of the high pressure crank, and N that of the low.

In compound engines of this kind, the cut-off in the high pressure

cylinder is usually controlled by the governor, and that of the low is either fixed or better varied by hand.

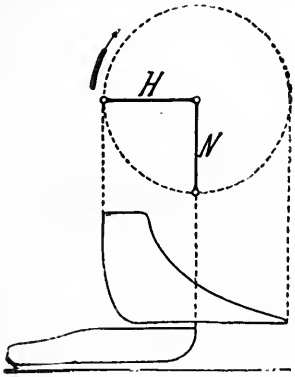



Fig. 965.

**Ratio of Cylinder Volumes of Compound Engines.**

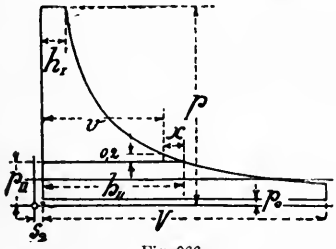



Fig. 966.

From the theoretical diagram, fig. 966, the ratio of the cylinder volumes can be determined :

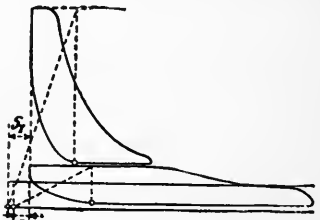
$t$ = the temperature of the entering steam.
$p$ = pressure of the entering steam.
$t_0$ = the temperature of the exhaust steam.
$p_0$ = pressure of the exhaust steam.

The mean temperature of the cylinders should be equal to half the total fall of temperature. Let the range of temperature difference in the two cylinders be taken as nearly equal as possible, then

$$t_u = \frac{t + t_0}{2}$$

From this temperature and corresponding pressure $p$, the line passing through the point in the curve at the height $p_{iii}$, will be the division line between the two cylinder diagrams, and $b_{ii}$ as the admission line of the low pressure cylinder diagram, an allowance of about 3 lbs. pressure (·2 atmosphere) being made for the drop between

Fig. 967.



the cylinders, then the volume of the high pressure cylinder $v$ will be a little less than $b_{ii}$. The diagram can be then rounded off and corrected, when it will appear as in fig. 967. Sometimes the endeavour is made to exactly equalize the work in the two cylinders, but although for many reasons it is good practice, the equality can only happen at certain loads unless the low pressure cylinder is provided with a variable expansion gear worked by hand.

### Receivers for Compound Engines

The receiver was formerly merely a large pipe between the cylinders of compound engines, or in some cases a wrought-iron barrel lagged and cased, but now they are often steam jacketed, and sometimes constructed as in fig. 968 with tubes. An ordinary form is that shewn in fig. 970, which is simple and cheap to make.

One of the most important points to note is that the receiver and jacket should be efficiently drained.

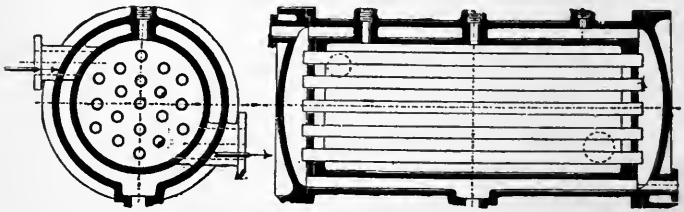


Fig. 968.—Receiver with tubes.*

* "Zeitschrift d. Verein Deutsch Ingenieur," 1888, plate 15.

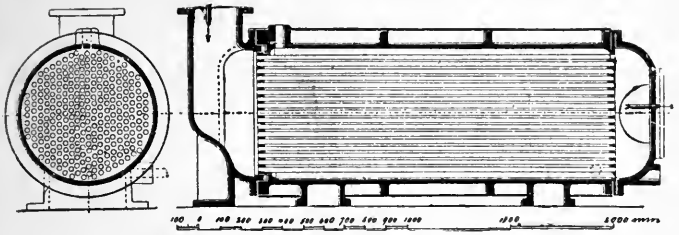


Fig. 969.—Receiver with tubes for tandem engine.*

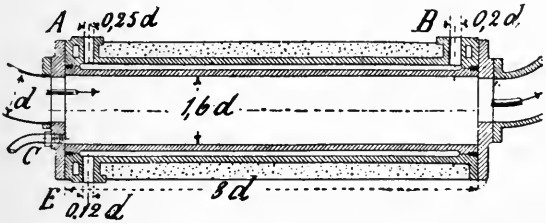



Fig. 970.—Ordinary jacketed receiver.

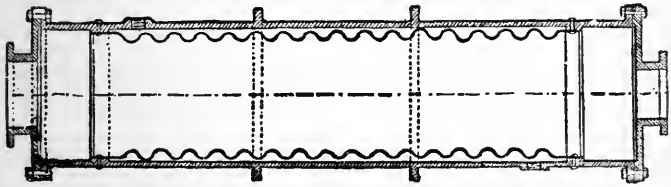


Fig. 971.—American jacketed receiver.†

## Triple Expansion Engines.

### a. Marine Engines.

The number of triple expansion engines built increases every year, and it is now the recognized type for marine engines with boiler pressure of about 160 lbs. per square inch. Four different arrangements are in use.‡

---

* "Zeitschrift d. Verein Deutsch Ingenieur," 1890, plate 22.

† *Engineering*, 1891. p. 750.

‡ These arrangements are from a paper by Otto J. Müller, jun., "Zeitschrift d. deutsches Verein Ingenieur," 1887, page 445. See also "Proceedings of the Institution of Mechanical Engineers," July, 1891.

(1.) In fig. 972 there are cranks at right angles, and No. I. cylinder is placed tandem fashion on the top of No. II. A special variety with No. II. cylinder annular, and placed round No. I., see fig. 973.

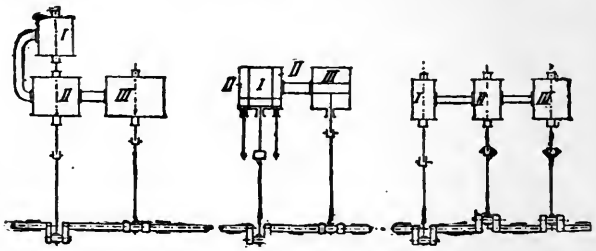



Fig. 972. Fig. 973. Fig. 974

(2.) Fig. 974 shews the very usual arrangement with three cranks at 120° to each other, the three cylinders side by side.

(3.) In fig. 975, there are two high pressure cylinders, Nos. I.

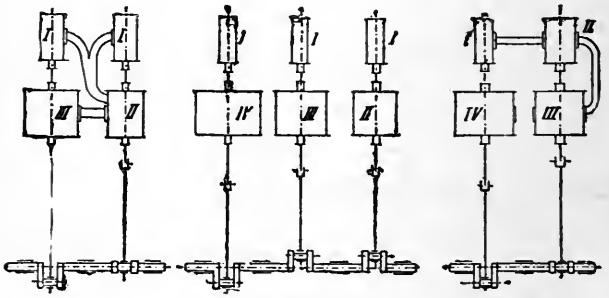



Fig. 975. Fig. 976. Fig. 977.

I. placed over Nos. II. and III.; in this arrangement there are two cranks at right angles to each other. An elaboration of this arrangement for quadruple expansion is given in fig. 976.

(4.) A better arrangement for quadruple expansion is shewn in fig. 977.

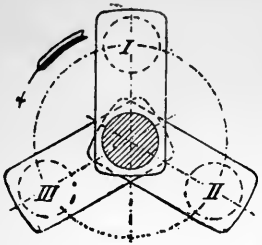



Fig. 978.

The cranks of the triple expansion marine engines may be arranged in order I., II., III., as in fig. 978, with the ship going ahead, so that the steam continuously expands in the shortest possible time while doing its work.*

* "Zeitschrift d. Verein Deutsch Ingenieur," 1886, No. 24.

TABLE 130.—**Leading Particulars of Triple-Expansion Condensing Engines, for 150 lbs. working pressure.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Stroke of all three cranks H | 16 | 24 | 32 | 40 | 48 | 56 | 64 | 72 | 80 |
| I. Diameter of high pressure cylinder . . $d_1$ | 9 | $13\frac{1}{2}$ | 18 | $22\frac{1}{2}$ | 27 | 32 | 36 | 40 | 44 |
| II. Diam. of intermediate pressure cylinder . $d_2$ | $14\frac{1}{4}$ | $21\frac{3}{4}$ | 29 | 36 | 44 | 52 | 59 | 66 | 72 |
| III. Diameter of low pressure cylinder . . $d_3$ | 24 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 118 |
| Proportion of cylinder volumes (in round numbers) . . II. : I. | 2·5 | 2·6 | 2·6 | 2·6 | 2·7 | 2·6 | 2·7 | 2·7 | 2·7 |
| Proportion of cylinder volumes (in round numbers) . . III. : II. | 2·8 | 2·8 | 2·8 | 2·8 | 2·7 | 2·6 | 2·6 | 2·7 | 2·7 |
| Proportion of cylinder volumes (in round numbers) . . III. : I. | 7·1 | 7·1 | 7·1 | 7·1 | 7·1 | 7·0 | 7·1 | 7·3 | 7·2 |
| Revolutions per minute $n$ | 200 | 140 | 120 | 100 | 85 | 77 | 70 | 66 | 60 |
| Piston speed in feet per minute . . . . | 530 | 560 | 640 | 660 | 680 | 710 | 740 | 790 | 800 |
| $N_i$ with 150 lbs. pressure $N_i$ | 250 | 600 | 1200 | 2000 | 2800 | 4000 | 5600 | 7400 | 9300 |
| Steam used in lbs. per indicated H.P. per hour . | 16·1 | 15·63 | 15·63 | 15·00 | 14·6 | 14·1 | 13·7 | 13·45 | 13·23 |

All Dimensions are given in Inches.

### Stationary Triple-Expansion Engines.

The triple-expansion engine does not offer such great advantages for use on land as for use at sea. The amount of steam used per HP is no doubt less, especially when pressures up to 160 lbs. per square inch are employed, than with simple or compound engines using lower pressures. The disadvantages of triple-expansion engines consist of an increased number of moving parts, by about one-third, and the cost of maintenance and repairs are increased. The high pressures render it less easy to keep the steam pipes and joints steam tight. The power absorbed with the engine running empty is greater than with simple and compound engines.

Professor Schöter gives an interesting account of experiments with a triple-expansion engine built by the Augsburger Engine Company in the Zeitschift d. Verein deutsches Ingenieur, 1890, No. 1.

The engine had two cranks at 90°; the (I) high and (II) intermediate cylinders were placed tandem with one piston rod common to the two, and the (III) low-pressure cylinder on the other side of the fly-wheel.

The working pressure was 150 lbs. per square inch, and the engine condensing; the normal HP at 70 revolutions per minute was 200. For the leading dimensions, see Table 131.

TABLE 131.—**Leading Particulars of Triple-Expansion Engine.**

| | High Pressure Cylinder I. | | Intermediate Pressure Cylinder II. | | Low Pressure Cylinder III. | |
|---|---|---|---|---|---|---|
| | Front. | Back. | Front | Back. | Front. | Back. |
| Diameter of pistons . | 11·102 | | 17·75 | | 27·61 | |
| Diameter of piston rods . . . | 2·95 | 3·35 | 3·35 | 0 | 3·35 | 3·35 |
| Stroke . . . . | 39·37 | | 39·37 | | 39·39 | |
| Ratio of cylinder vols. | 1 | | 2·73 | | 6·63 | |
| Ratio of cylinder vols. | — | | 1 | | 2·34 | |
| $P_m$ in lbs. per square inch . . . | 48·36 | 46·65 | 12·83 | 13·11 | 12·40 | 12·30 |

Dimensions in Inches.

The values of $P_m$ are from the mean of five different experiments.

A set of indicator diagrams to a reduced scale with pressures in atmospheres is given in fig. 979.

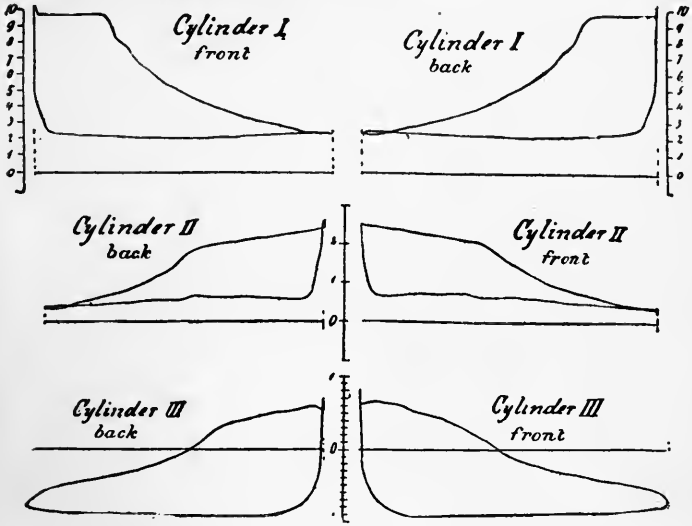



Fig. 979.

| | Indicated H.P. | | Indicated H.P. |
|---|---|---|---|
| Cylinder I., front . . | 31·7 | Cylinder I., back . . | 31·4 |
| Cylinder II., back . . | 20·1 | Cylinder II., front . . | 19·5 |
| Cylinder III., back . . | 48·5 | Cylinder III., front . . | 49·3 |

Total Indicated H.P. . . 200·5.

The steam was taken from a water tube boiler by Dürr & Co., Ratinger, Düsseldorf, with a permitted pressure of 190 lbs. per sq. inch, 150 lbs. only being used during the trials. The heating surface of the boiler was 1722 square feet. The steam used per I.H.P. per hour was 12·52.

From diagrams taken with the engine running light, gave 23·8 I.H.P., about 11·5 per cent. of the normal power.

In the next table the performance of some examples of triple expansion engines is given from actual practice.

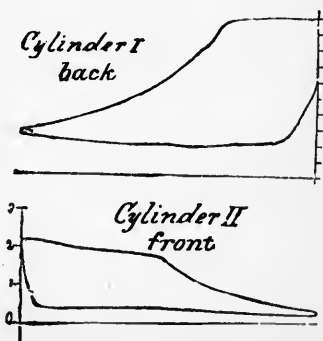



Fig. 980.

TABLE 132.—**Particulars of Triple-Expansion Engines from Actual Practice.**

**Horizontal Type.**

| Cylinder Diam. High. | Intermediate. | Low. | Stroke. | Revolutions per Minute. $n$ | Steam Pressure. | Indicated H.P. $Ni$ | Steam in lbs. per I.H.P. per Hour. Guaranteed | Steam in lbs. per I.H.P. per Hour. Attained | Heating Surface of Boiler in square feet. | Builder of Engine. | User of Engine. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23⅝ | 35½ | 53¼ | 63 | 65 | 150 | 1000 | 12·13 | 11·62 | — | Sulzer Bros. | Brunswick Flax Works. |
| 21⅝ | 33½ | 48⅛ | 47¼ | 68 | 150 | 700 | 12·13 | 11·80 | — | Sulzer | H. Haggemacher, Buda Pesth. |
| 19¾ | 29½ | 47¼ | 55¼ | 65 | 150 | 700 | 13·78 | 12·45 | 6264 | Augsburg Engine Co. | Thread Works, Göggingen. |
| 18¾ | 29½ | 43½ | 41½ | 70 | 150 | 450 | 13·23 | 12·01 | — | Sulzer Bros. | Kinkindaer Steam Mill. |
| 14¼ | 22⅝ | 35½ | 43½ | 70 | 150 | 400 | 13·23 | — | — | Görlitz Engine Works | L. Loewe & Co., Berlin. |
| 13½ | 21⅝ | 33⅜ | 39⅜ | 70 | 170 | 330 | 13·00 | — | — | Görlitz Engine Works | Hansa Mill, Bremen. |
| 14¾ | 21⅝ | 31½ | 39⅜ | 70 | 150 | 240 | 13·23 | — | — | Görlitz Engine Works | Ammunition Works, Spandau. |
| 11 | 15¾ | 23⅝ | 27½ | 85 | 205 | 225 | 14·33 | 13·44 | 1614 | Nuremberg Engine Works | N. Wiederer, Fürth. |
| 9¾ | 15· | 22½ | 31½ | 85 | 175 | 200 | 14·33 | 13·44 | 1280 | Nuremberg Engine Works | C. Sclenk, Rotha, S. |
| 11 | 17¾ | 27½ | 39⅜ | 70 | 150 | 200 | — | 12·4<br>12·0 | 1764 | Augsburg Engine Co. | Augsburg Engine Co. |
| **Vertical Type.** | | | | | | | | | | | |
| 21⅝ | 35 | 55¼ | 35½ | 85 | 150 | 825 | 12·7 | — | 6963 | Sächs Engine Works | Steam Mill, Wansbeck. |
| 23⅜ | 37¾ | 53¼ | 23⅝ | 90 | 157 | 700 | 13·0 | — | — | G. Luther, Brunswick | Dietrich Bros., Weissenfels. |
| 23⅜ | 37¾ | 53¼ | 23⅝ | 90 | 157 | 480 | 13·0 | — | — | G. Luther, Brunswick | Wittener Rolling Mills, Duisburg. |

Dimensions in Inches.

**Proportions of Cylinder Volumes with equal strokes for Triple-Expansion Engines.**

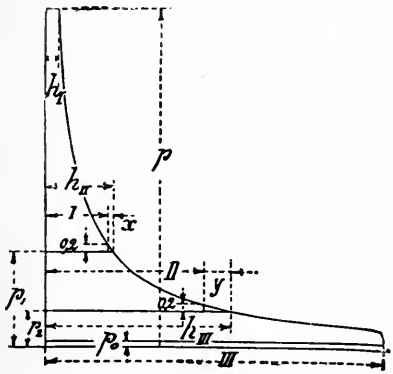



Fig. 981.

From the diagram fig. 981, the proportions of cylinder volumes can be determined :

$t$ = temperature of entering steam.
$p$ = pressure of the same.
$t_1$ = temperature of steam in inter. cylinder.
$p_1$ = pressure of steam in inter. cylinder.
$t_2$ = temperature of steam in LP cylinder.
$p_2$ = pressure of steam in LP cylinder.
$t_0$ = temperature of exhaust steam.
$p_0$ = pressure of exhaust steam.

Taking the mean temperature to be half the extreme difference,

$$t_1 = \frac{2t + t_0}{3}$$

$$t_2 = \frac{t + 2t_0}{3}.$$

Then taken the corresponding pressures $p_1$ and $p_2$, the diagram can be divided as with the one for compound engines, a drop being allowed of 3 lbs. per square inch. $h_{II}$ and $h_{III}$ will be respectively the points of cut-off from the inter. and LP cylinders ; the diagram may then be corrected for compression and losses.

Figs. 982, 983, shew the pistons and cranks of triple-expansion engines in various positions.

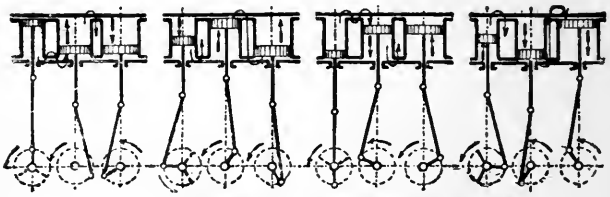


Fig. 982.—Triple-expansion engine with two receivers.

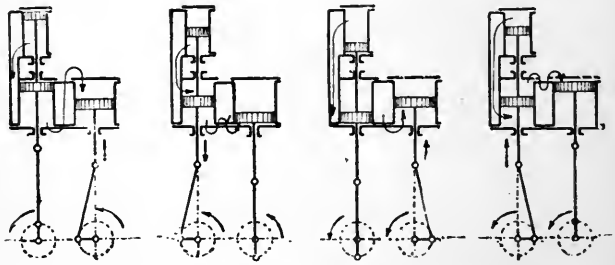


Fig. 983.—Semi-tandem triple-expansion engine with two receivers.

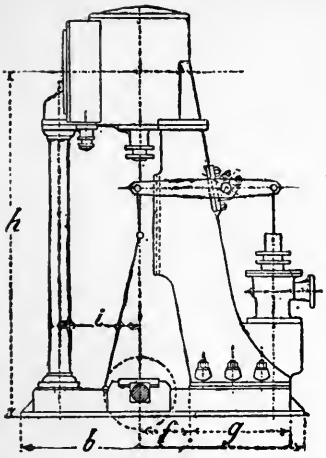


Fig. 984.

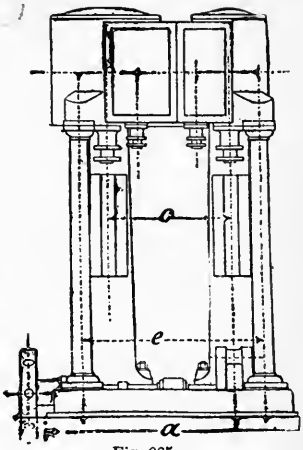


Fig. 985.

TABLE 133.—**Compound Engine for Screw Steamers**
(Figs. 984, 985).

| Stroke of both pistons . . H | 7½ | 9¾ | 11¾ | 13¾ | 15¾ | 19¾ | 23¾ |
|---|---|---|---|---|---|---|---|
| Diam. of high-press. piston *d* | 5⅜ | 6¾ | 7⅞ | 9¼ | 11¼ | 13¾ | 17 |
| Diam. of low-press. piston . D | 8¼ | 10⅝ | 12¼ | 14⅝ | 17¾ | 21¾ | 26½ |
| Proportion of cylinder vols. $\frac{v}{d}$ | 2·5 | 2·5 | 2·5 | 2·5 | 2·5 | 2·5 | 2·5 |
| Proportion of H : *d* . . | 1·5 | 1·5 | 1·5 | 1·5 | 1·4 | 1·4 | 1·4 |
| Revolutions per minute . *n* | 280 | 260 | 245 | 230 | 210 | 180 | 150 |
| Piston speed in ft. per min. *c* | 365 | 420 | 470 | 515 | 530 | 590 | 590 |
| I.H.P. with 105 lbs. boiler press. | 25 | 50 | 80 | 120 | 180 | 270 | 400 |
| Dimension . . . . *a* | 23⅝ | 29½ | 37½ | 45½ | 55 | 73 | 90 |
| „ . . . . *b* | 23⅝ | 29½ | 37½ | 45½ | 55 | 73 | 90 |
| „ . . . . *c* | 9½ | 11¾ | 16½ | 19¾ | 23⅝ | 37½ | 47½ |
| „ . . . . *e* | 19¾ | 24⅝ | 29½ | 34½ | 41½ | 55 | 70¾ |
| „ . . . . *f* | 5½ | 7 | 8¼ | 9¾ | 11 | 13¾ | 16½ |
| „ . . . . *g* | 10¼ | 12⅝ | 15½ | 17¾ | 20½ | 25⅝ | 30¾ |
| „ . . . . *h* | 41½ | 51 | 59 | 70¾ | 78¾ | 98 | 118 |
| „ . . . . *i* | 7⅞ | 9¾ | 12⅝ | 15 | 17 | 21⅝ | 26 |
| Weight in cwts. . . . G | 15¾ | 31½ | 55 | 88½ | 137 | 236 | 452 |

All Dimensions are given in Inches.

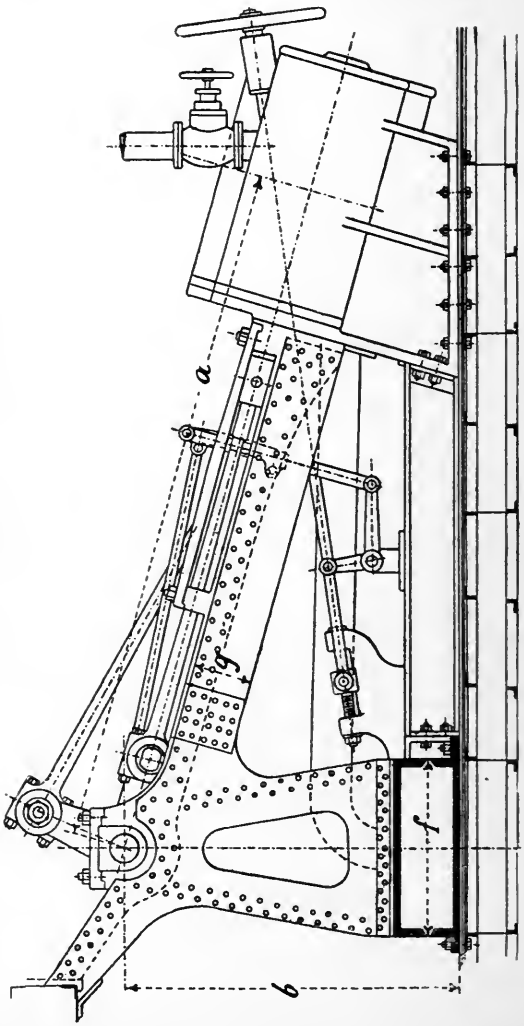



Fig. 936.

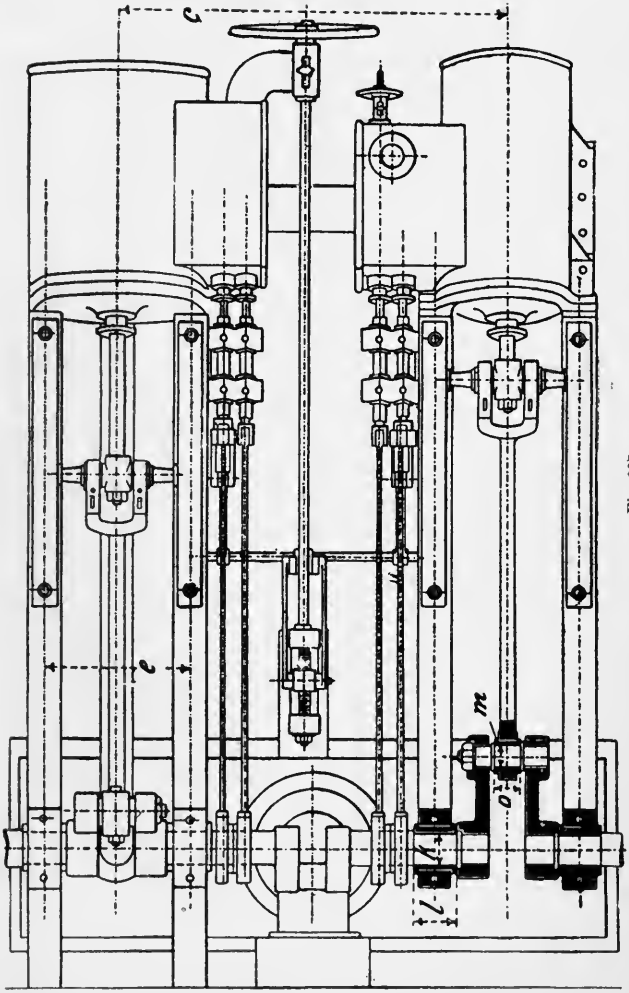



Fig. 987

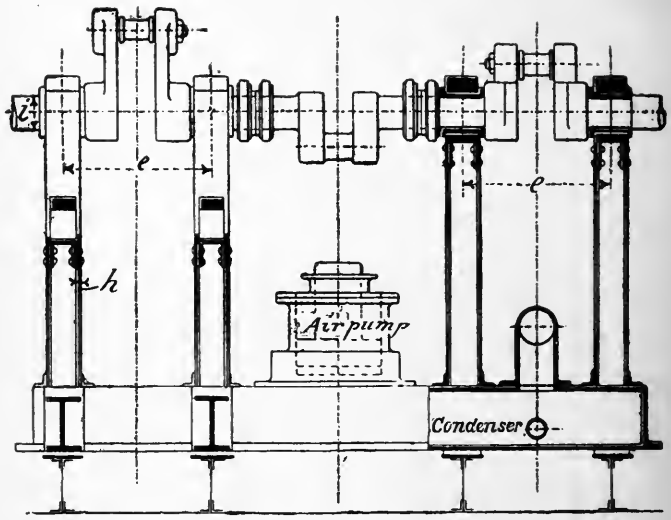



Fig. 988.

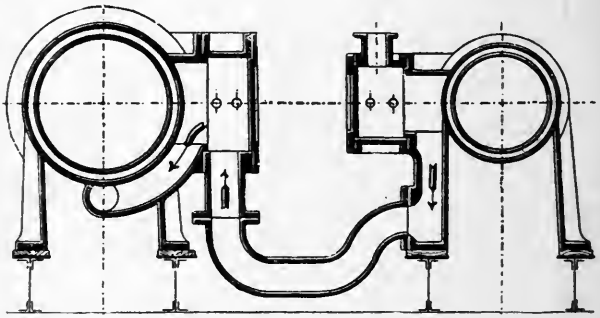


Fig. 989

TABLE 134.—**Compound Engines for Paddle Steamers, 105 lbs. Boiler Pressure** (Figs. 986—989).

| | | | | | lbs. pressure. | | | | | | | | | Dia. of paddle-shaft. | Bearings. | | Crank-pin. | | Weight in cwts. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | $d$* | D* | $\frac{V}{v}$† | $n$ | $p$ | H.P. | $a$ | $b$ | $c$ | $e$ | $f$ | $g$ | $h$ | $i$ | $k$ | $l$ | $m$ | $o$ | G |
| $19\frac{3}{4}$ | $12\frac{1}{4}$ | $19\frac{3}{4}$ | 2·5 | 50 | 120 | 40 | $86\frac{5}{8}$ | $47\frac{1}{4}$ | 51 | $19\frac{3}{4}$ | $23\frac{3}{4}$ | 7 | $\frac{5}{16}$ | $5\frac{7}{8}$ | $5\frac{1}{8}$ | $7\frac{7}{8}$ | $3\frac{1}{2}$ | $6\frac{3}{4}$ | 79 |
| $23\frac{3}{4}$ | $14\frac{1}{2}$ | $23\frac{3}{4}$ | 2·5 | 46 | 120 | 60 | $102\frac{3}{8}$ | 51 | 63 | $23\frac{3}{4}$ | $29\frac{1}{2}$ | $9\frac{1}{2}$ | $\frac{11}{32}$ | $6\frac{1}{2}$ | $5\frac{3}{4}$ | $8\frac{5}{8}$ | $4\frac{1}{8}$ | $7\frac{1}{2}$ | 128 |
| $31\frac{1}{2}$ | 18 | $31\frac{1}{2}$ | 2·5 | 40 | 120 | 125 | 134 | 57 | $78\frac{3}{4}$ | $29\frac{1}{2}$ | $33\frac{1}{2}$ | $11\frac{3}{4}$ | $\frac{11}{32}$ | $7\frac{7}{8}$ | $6\frac{3}{4}$ | $9\frac{1}{2}$ | $5\frac{1}{8}$ | $8\frac{5}{8}$ | 295 |
| $39\frac{1}{2}$ | $21\frac{3}{4}$ | $39\frac{1}{2}$ | 2·5 | 38 | 120 | 210 | $165\frac{1}{2}$ | 63 | $94\frac{1}{2}$ | $36\frac{1}{4}$ | $39\frac{1}{2}$ | $15\frac{3}{4}$ | $\frac{3}{8}$ | $9\frac{1}{2}$ | $8\frac{1}{4}$ | $11\frac{1}{2}$ | $6\frac{1}{2}$ | $10\frac{1}{4}$ | 551 |
| 47 | $25\frac{3}{4}$ | 47 | 2·5 | 35 | 120 | 350 | 197 | 67 | 110 | $43\frac{1}{4}$ | $43\frac{1}{4}$ | $19\frac{3}{4}$ | $\frac{7}{16}$ | $11\frac{3}{4}$ | $9\frac{3}{4}$ | $13\frac{1}{2}$ | $7\frac{7}{8}$ | $12\frac{5}{8}$ | 925 |
| 55 | $29\frac{1}{2}$ | 55 | 2·5 | 32 | 120 | 500 | 232 | 71 | 126 | 51 | $47\frac{1}{4}$ | $25\frac{5}{8}$ | $\frac{15}{16}$ | $13\frac{3}{4}$ | $11\frac{3}{4}$ | $15\frac{3}{4}$ | $9\frac{1}{2}$ | 15 | 1377 |
| 63 | $34\frac{3}{4}$ | 63 | 2·5 | 30 | 120 | 700 | 268 | 75 | 141 | 59 | 51 | $31\frac{1}{2}$ | $\frac{1}{2}$ | $15\frac{3}{4}$ | $13\frac{3}{4}$ | 18 | 11 | 17 | 1968 |

* D = Diameter of low-pressure piston; $d$ = Diameter of high-pressure piston.
H = Stroke of both pistons.
† V = Volume of low-pressure cylinder; $v$ = Volume of high-pressure cylinder.

All Dimensions are given in Inches.

# SECTION IX.

## INDICATOR AND INDICATOR DIAGRAMS.

In the beginning of section IV. on Valve gears, page 151, indicator diagrams have been mentioned, and a method of drawing an approximate expansion curve has been given; in this section the subject is given in more detail, with examples of diagrams from actual practice.

### The Indicator.

The original indicator, as invented and made by James Watt, has been since improved in detail although the principle remains the same. The object of the improvements has been to decrease the weight of the moving parts and to make the stroke of the piston as short as possible.

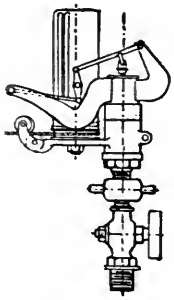


Fig. 990.—Richards' Indicator.

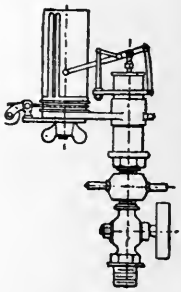


Fig. 991.—Thompson's Indicator.

Amongst the earliest improvements was that of Richards, fig. 990, who reduced the stroke of the piston but retained the longer stroke of the pencil by introducing a system of light levers which also formed a parallel motion for the same. This indicator is perhaps the most largely used, and with ordinary speeds gives very good results. The union or coupling by which this indicator is attached

to the cock, is cut with threads of different pitches in the two parts, that which screws on to the indicator itself having a fine thread, and that part which screws on to the cock has a coarse thread ; the part of the cock is conical and fits a corresponding taper on the indicator ; this makes a very neat arrangement, and easy to take on and off.

Fig. 991 shews a modification of Richards' indicator by Thompson. A further modification by Crosby, fig. 992, has many points of interest, the spring fixed rigidly only to the cylinder cover, and is attached to the piston by a ball and socket joint ; the spring is also double wound, right and left hand, an arrangement intended to do away with any tendency to twist as the spring compresses. The whole indicator is much smaller than Richards', and better adapted

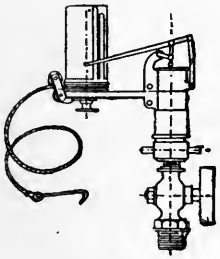


Fig. 992.—Crosby's Indicator.

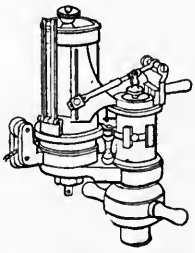


Fig. 993.—Darke's Indicator.

for very high speeds. The coupling for attaching the indicator is like that of Richards, but has a right and left hand screw instead of two right hand threads of different pitch ; this makes it much less easy to take on and off. A still smaller indicator is that of Darke, fig. 993, where the pencil is guided by a loose slide in a slot ; the coupling is the same as that of Richards, and is interchangeable with it. This indicator is arranged for very high speeds, and is fitted with a dentent or catch to hold the paper drum whilst string is being hooked on.

The stroke of the paper drums in all these indicators is necessarily much less than that of the engine. To reduce the stroke a moving lever is generally used, and care should be taken in leading the string to the indicator that its motion is always truly in the direction of the axis of the string.

A segment of wood fitted to the lever of correct proportion to give the right stroke will, if of sufficient extent, always ensure the string

moving correctly. The levers may be made of wood, or better of iron. Figs. 994—997 shew an example of levers. The choice of arrangement of indicator gear necessarily depends on the style and

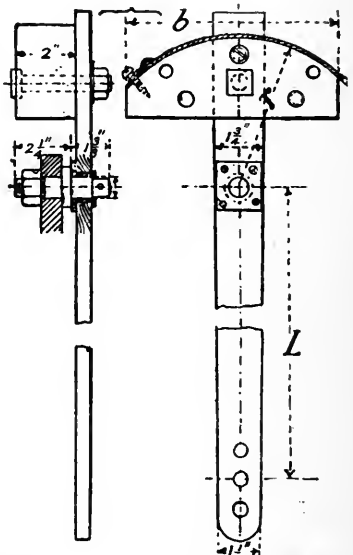



Fig. 994. Fig. 995.

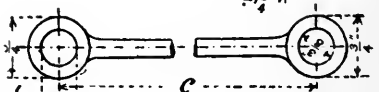



Fig. 996.

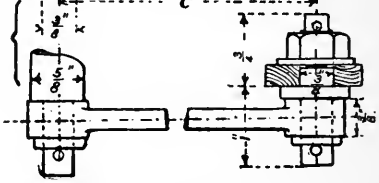



Fig. 997.

position of the engine to be indicated; sometimes the lever may have to be attached to the walls or roof of the engine-room, but now the best makers will supply self-contained indicator gear with the engines they make.

Fig. 998 shews in outline an indicator gear of the ordinary lever

kind, fitted to a horizontal girder engine. Fig. 999, a reducing gear with different sized drums pulled round by a string from an arm fixed to the cross head ; these arrangements are not so simple as the

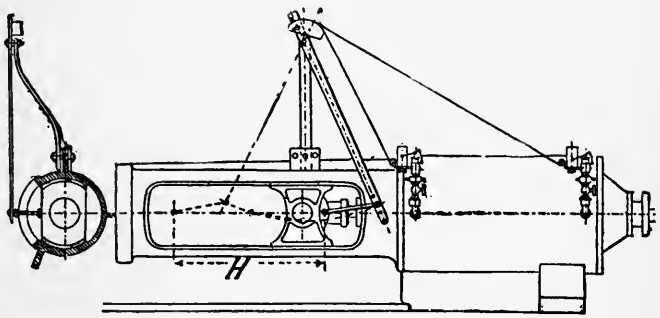


Fig. 998.

ordinary lever ; the lower end of the lever should be connected to a pin in the crosshead by a link and not, as is often done, by a slot in

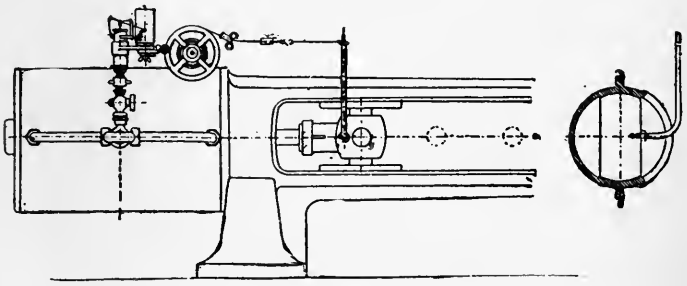


Fig. 999.

the end of the lever which gives more error to the motion of the paper due to the arc described by the end of the lever.

The practice of putting the indicator on a system of pipes from both ends of the cylinder, fig. 999, to which is fitted a 3-way cock, gives very pretty results (fig. 1000) by enabling diagrams from both ends of the cylinder to be produced on one card, but is not to be re-

Fig. 1000.

commended, as elements of inaccuracy are thus introduced. For very exact work two indicators should be used, one for each end, and occasionally they should be changed over from one end to the other to eliminate a possible chance of error. An example of an extreme case of error from long pipes is given on page 378, fig. 1017 ; here the pipes were lead to the centre, and a cock fixed at each end, not even with a 3-way cock in the middle.

Fig. 1018 shews diagram taken from same engine with same load on with indicator fixed direct on each end of cylinder, the pipes having been removed.*

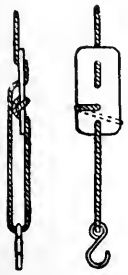


Fig. 1001.

Some operators prefer to have a sliding joint in the string by using a piece of wood or metal as in fig. 1001 ; this may be of use with slow speeds, but with high speeds a dead length string with a small ring at the end, and a hook on the indicator strings or *vice versa*, is the best, or the string can be arranged to pull through the edge of the wood segment on the lever and up to a knot, and can be held whilst taking the diagram, and thus the hook need not be used.

It is good before starting to indicate an engine to put the string on stretch in the engine-room, so as to get it to the same temperature and dryness as the surrounding air ; if this be done, very little trouble will occur with the string whilst in use. In indicating the pencil should be pressed to the paper very gently, and if the engine has only been running for a few days or hours, that is, if the engine is new, the piston of the indicator should be taken out very frequently and the cylinder sponged out : the lower limits of a diagram are very liable to error from dirt accumulated in the cylinder, and an old indicator should always be used on a new engine ; no instrument regarded as a standard should be applied to any engine which has not run itself clean from sand and dirt off the steam ports and passages. If after having taken a few diagrams the atmospheric line appears to be a trifle higher than on the first diagram it is a sure sign that the cylinder is foul, and it should be sponged out before any more diagrams are taken.

---

* Mr. Haeder says that the bosses for indicator cocks are tapped with 1" English thread. In England the custom is to tap with $\frac{3}{4}$" Whitworth thread.

To calculate the power from an indicator diagram, the average or mean pressure on the piston is found either by using a planimeter or more conveniently by the method of equidistant ordinates. The diagram is divided into ten equal parts, figs. 1002, 1003, and the mean height of each part is measured by the scale corresponding to the spring used in the indicator; the ten mean heights are then added together and divided by ten; this gives the mean pressure on the piston with fair accuracy. A quick and accurate way of measuring the added lengths or heights of the ordinates is to take a narrow strip of paper and to mark off with a sharp pencil the length of the first division, then run the strip to the next and make a mark, and so on to the tenth, then measure the total length between the first and last mark and point off for dividing by ten; this gives the mean pressure, which multiplied by the area of the piston in square inches by twice the stroke in feet, and by the number of revolutions per minute, and divided by 33,000, gives the indicated horse-power. If diagrams be taken with a load on the engine and then with the load off, the difference between the two results will give the useful or effective horse power. It is not easy to get accurate measurements of power from a large engine when running without load, and therefore it is seldom possible to get the true effective load by this means; but a fairly accurate idea of the power taken by individual machines out of a large number driven by one engine may be obtained by indicating the engine with the particular machine on and then with it off, and taking the difference for the power required for driving the machine.

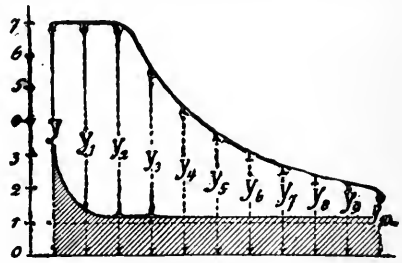



Fig. 1002.

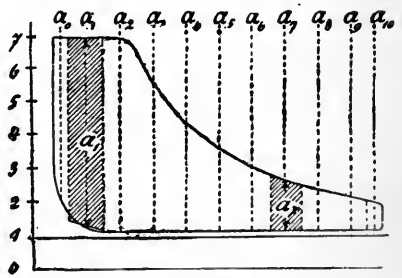



Fig. 1003.

## Indicator Diagrams.

### Combined Diagrams from Compound Engines.

The proportion of the area of the combined diagrams to the area of the figure A, B, C, D, E, gives approximately the efficiency of the proportion of the efficiency of the engine. To combine the diagrams from the two cylinders of a compound engine they may be laid out

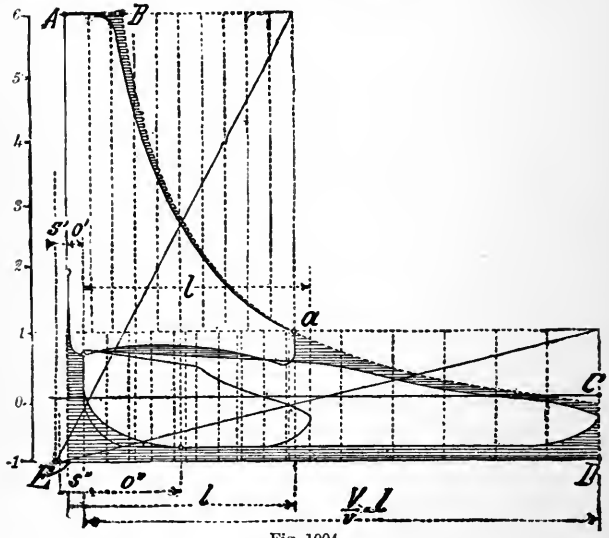



Fig. 1004.

to the same scale and length, $l$, so that the admission line of the low pressure diagram comes just to the beginning of the compression $o^1$ of high pressure diagram; the low pressure diagram is then laid out to a length equal to the proportion of the cylinder volumes $\frac{V}{v} \times l$.

The theoretical expansion curve is drawn through the point $a$, and the shaded portion will show the theoretical loss, fig. 1004.

$s'$ = the clearance of the high-pressure cylinder.

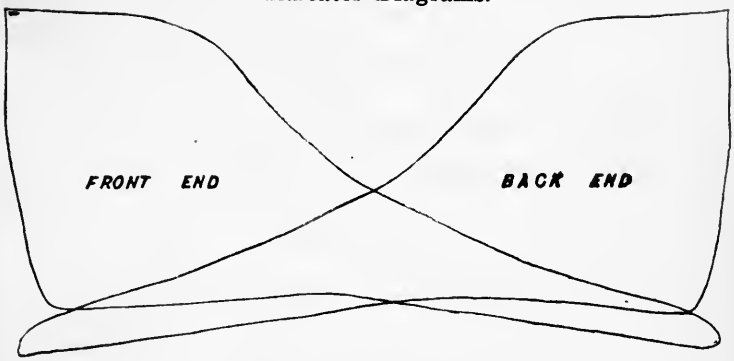
$s''$ = the clearance of the low-pressure cylinder.

$o'$ = the compression in high-pressure cylinder.

$o''$ = the compression in low-pressure cylinder.

The effect of laying out combined diagrams, is to produce a diagram which should represent what would take place in one cylinder of the volume of the low-pressure cylinder of the compound engine.

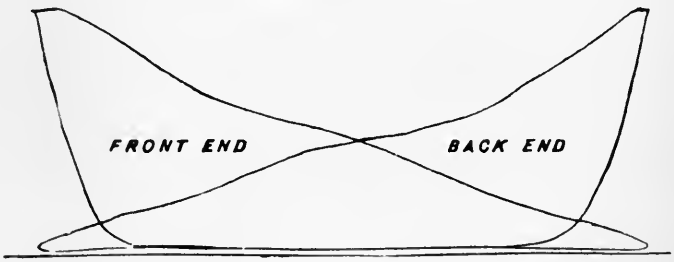
**Indicator Diagrams.**




Scale $\frac{1}{64}$

HIGH PRESSURE CYLINDER

Fig. 1005.




Scale $\frac{1}{32}$

LOW PRESSURE CYLINDER

Fig. 1006.

Diagrams* from compound engine with Davey Paxman's valve gear controlled by the governor. The two valves are driven by separate eccentrics, and the cut-off valve works on a false port face between the main and cut-off valves.

* See Royal Agricultural Society's report of Newcastle meeting, 1887.

### Diagrams from Actual Practice.

Scales of all are given in fractions of an inch to one pound per square inch.

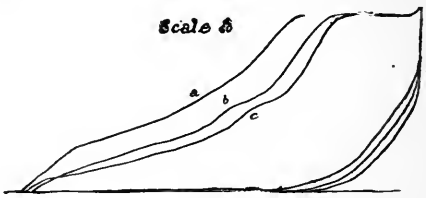
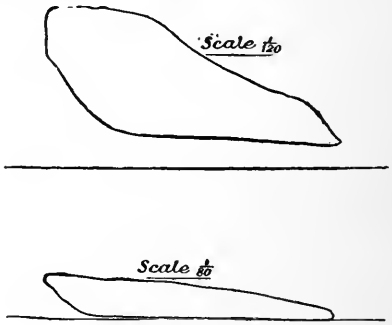



Fig. 1007.

*Diagrams from a portable engine fitted with single valve controlled by Hartnell's crank-shaft governor. Cylinder $8\frac{1}{2}''$ diameter, stroke 12″.

*a.* 127 revolutions per minute 13·9 indicated HP.
*b.* 129 revolutions per minute 10·8 indicated HP.
*c.* 130 revolutions per minute 10·1 indicated HP.




Figs. 1008, 1009.

Diagrams from compound undertype engine with high-pressure cylinder valve controlled by Hartnell's governor low-pressure valve by simple eccentric.

High-pressure cylinder 8″ diameter.
Low-pressure cylinder $12\frac{3}{4}''$ diameter.
Stroke of both, 14″.
Revolutions per minute, 155.

* See reports of Cardiff meeting of the Royal Agricultural Society.

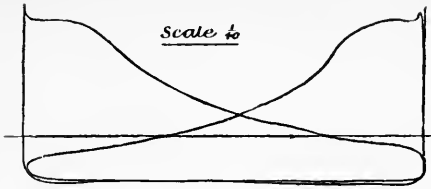



Fig. 1010.

Diagrams from condensing engine with Meyer valve gear and throttle valve. Cylinder 18″ diameter ; 30″ stroke. Revolutions per minute 60.

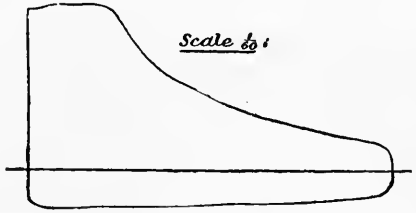
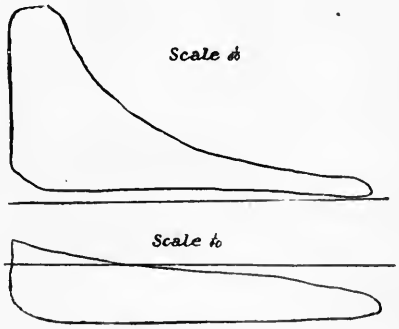



Fig. 1011.

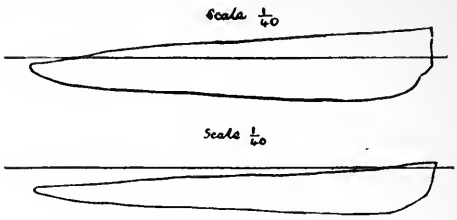
Diagram from condensing engine with cut-off valve controlled by Hartnell governor. Cylinder 16⅛″ diameter ; 36″ stroke. Revolutions per minute, 63.




Figs. 1012, 1013.

Diagrams from a compound horizontal engine, cranks at 90°, cut-off valve of high-pressure cylinder controlled by Hartnell's governor the valve of low-pressure cylinder worked by simple eccentric.

Diameter of high-pressure cylinder, 16″; low-pressure cylinder, 26″ Stroke of both, 36″. Revolutions per minute, 67.

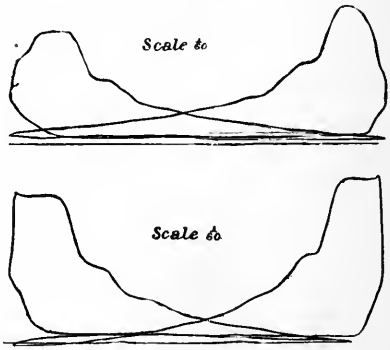



Figs. 1014, 1015.

Diagrams from a side lever marine engine by Miller & Ravenhill, dated 1839, used as a stationary engine.

Fig. 1016.

Diagram shewing a case of accidental re-admission by main valve over-running port face. Cylinder $11\frac{1}{4}''$ diameter, $24''$ stroke.

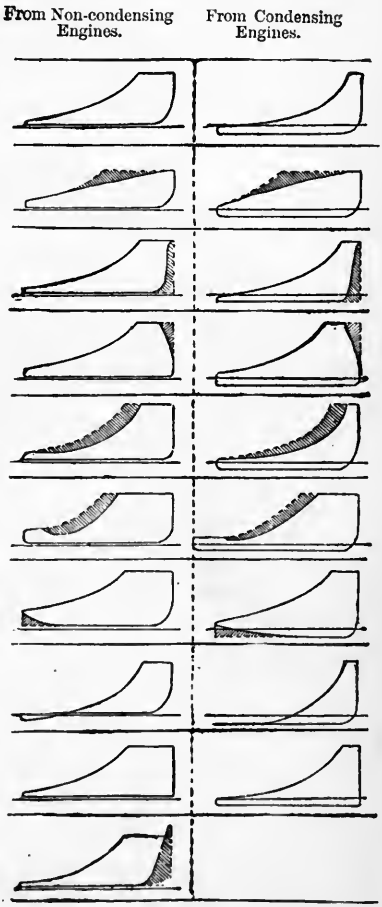



Figs. 1017, 1018

Fig. 1017 shews the effect of long pipes between cylinder and indicator.

Fig. 1018 from same engine with same load, the indicator being fixed direct on cylinder without any pipes. Cylinder $13\frac{1}{2}''$ diameter, $24''$ stroke, 100 revolutions per minute.

**Diagrams shewing the Defects in Valve Gears which may often be met with in Practice.**




Example of a normal indicator diagram, from an engine with good expansion gear.

Diagram shewing the effect of throttling.

Too early admission, with light fly-wheel.

Too late admission.

Leaking valves, allowing steam to pass after cut-off.

Re-admission after cut-off, caused by re-opening cut-off ports before main valve has closed the steam-port See page 192.

Too late opening of exhaust, or may be caused by exhaust being too small.

Load too light for size of engine.

Too little compression.

Too much compression.

Fig. 1019.

The shaded parts in the above diagrams shew the losses.

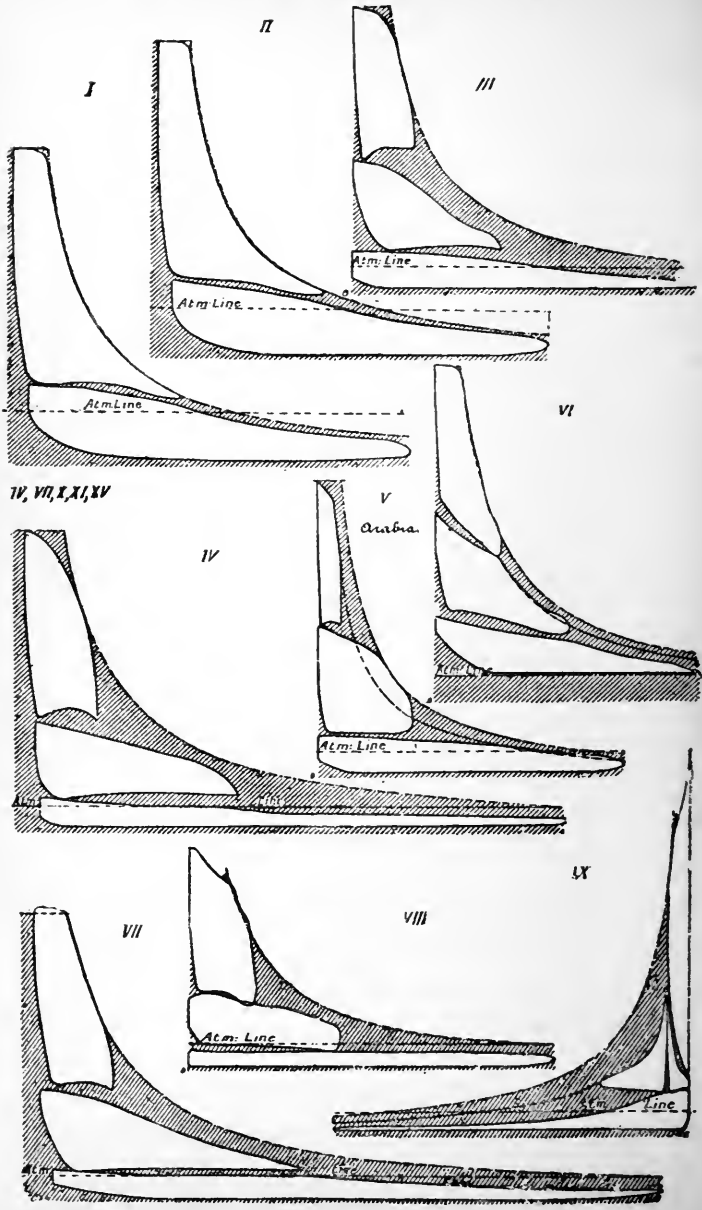
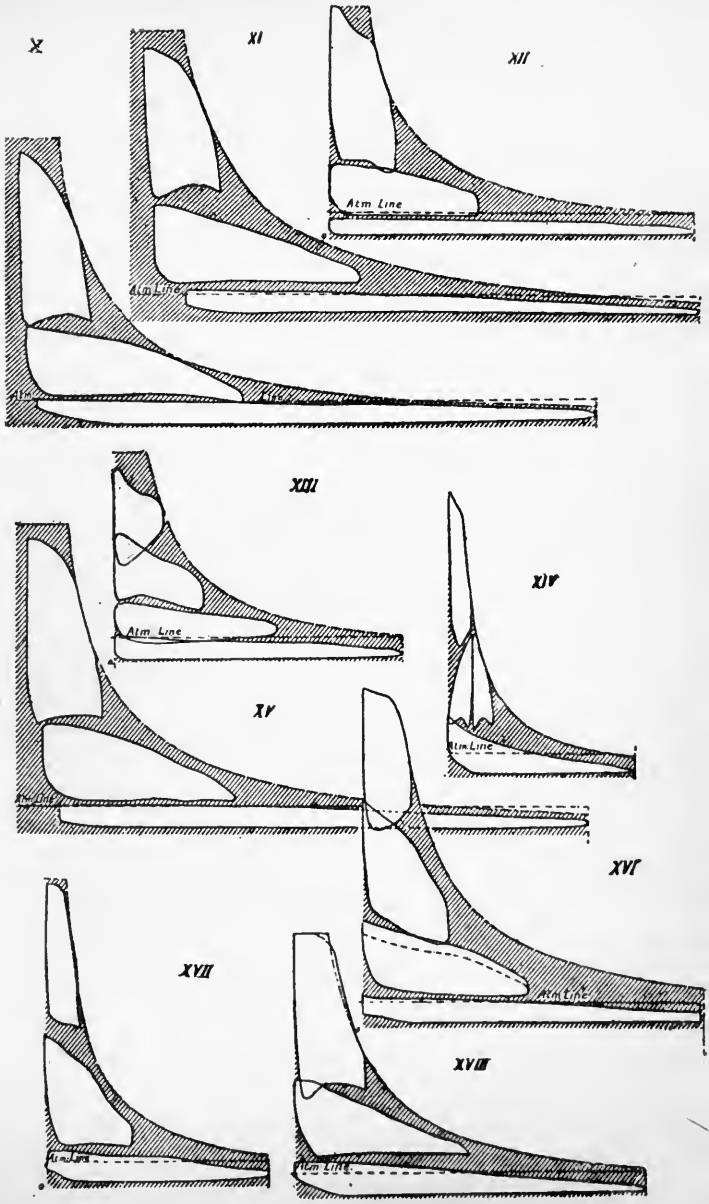

II
I
III
Atm: Line
Atm: Line
Atm: Line
VI
IV, VII, X, XI, XV
V
Aruba.
IV
Atm: Line
IX
VII
VIII
Atm: Line
Atm: Line

Fig. 1020.


X
XI
XII
Atm Line
Atm Line
Atm Line
XIII
Atm Line
XIV
Atm Line
XV
Atm Line
XVI
Atm Line
XVII
Atm Line
XVIII
Atm Line

**Diagrams from Triple-Expansion and Compound Engines, pages 380, 381.**

Nos. I. & II., S.S. Bachheibel.
III., S.S. Falkenburg.
IV., S.S. African.
V., S.S. Arabia.
VI., Stülchen's 3-cylinder compound.
VII., S.S. Para.
VIII., S.S. Aberdeen, with superheater efficiency ·67.
IX., S.S. Wanderer.
X., S.S. Stella.
XI., S.S. Lusitania.
XII., S.S. Aberdeen, with superheater efficiency ·65.
XIII., Adamson's quadruple-expansion efficiency ·71.
XIV., S.S. Isle of Dursey.
XV., S.S. Jungfrau.
XVI., S.S. Rimnag na Maia.
XVII., S.S. Sobraleuse.
XVIII., S.S. Nierstein.

The above diagrams are from a paper by Otto H. Müller, "Zeitschrift der Verein Deutsch. Ingenieur," 1887, page 445, and shew different ways of combining diagrams from compound engines.

## SECTION X.

### CALCULATIONS FOR POWER AND STEAM CONSUMPTION.

THE following terms and letters are used in these calculations:—

$N_i$ = the indicated horse-power.
$N_e$ = the effective horse-power.
Q = the effective surface of the piston in square inches.
H = the stroke in inches.
$n$ = the revolutions per minute.
$c$ = the piston speed in feet per minute.
$h$ = the admission or cut-off when H = 1.
P = the initial pressure in lbs. per square inch.
$k$ = expansion coefficient dependent upon the admission $h$, and the clearance $s$, see Table 135.
$s$ = the clearance space in terms of piston area, so that the length of the line $s$ on the diagrams, figs. 1022, 1023, represents the volume of the clearance space when H = 1.
$P_m$ = the mean pressure on the piston in lbs. per square inch.
$P_o$ = the back pressure in lbs. per square inch.
$\sigma$ = the sum of the losses of work by wire-drawing, compression, early opening of exhaust, back pressure, etc.

$$\text{then } c = 2Hn.$$

$$N_i = \frac{Q\ c\ P_m}{33{,}000};$$

The mean pressure $P_m = kp - (P_o + \sigma)$.

The expansion coefficient $k = h + (h + p)\ \log\epsilon\ \frac{1+s}{h+s}$; see Tables 135 and 169.

The back pressure $P_o$ of the exhaust steam is dependent on the terminal pressure $\omega$, and the size of the exhaust passages.

Table 137 gives the value of the back pressure for usual proportions, and for a speed of about 100 feet per second of the steam in the passages, allowance also being made for the sum of the losses $\sigma$.

TABLE 135.—**Value of the Expansion Coefficient $k$.**

| $h$ | Clearance space $s$. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% |
| 0·00 | 0·079 | 0·107 | 0·130 | 0·152 | 0·172 | 0·191 | 0·210 | 0·226 | 0·240 |
| 0·02 | 0·151 | 0·173 | 0·190 | 0·210 | 0·230 | 0·250 | 0·263 | 0·276 | 0·289 |
| 0·04 | 0·204 | 0·232 | 0·250 | 0·268 | 0·280 | 0·292 | 0·302 | 0·314 | 0·328 |
| 0·06 | 0·255 | 0·273 | 0·292 | 0·303 | 0·321 | 0·332 | 0·343 | 0·353 | 0·366 |
| 0·08 | 0·305 | 0·321 | 0·337 | 0·348 | 0·363 | 0·371 | 0·383 | 0·392 | 0·403 |
| 0·10 | 0·356 | 0·369 | 0·381 | 0·392 | 0·403 | 0·412 | 0·422 | 0·432 | 0·440 |
| 0·12 | 0·394 | 0·406 | 0·417 | 0·427 | 0·437 | 0·446 | 0·455 | 0·464 | 0·472 |
| 0·14 | 0·431 | 0·442 | 0·452 | 0·462 | 0·470 | 0·479 | 0·487 | 0·495 | 0·503 |
| 0·16 | 0·467 | 0·477 | 0·486 | 0·496 | 0·502 | 0·511 | 0·518 | 0·525 | 0·533 |
| 0·18 | 0·502 | 0·513 | 0·519 | 0·529 | 0·533 | 0·542 | 0·548 | 0·554 | 0·562 |
| 0·20 | 0·535 | 0·545 | 0·552 | 0·559 | 0·565 | 0·571 | 0·577 | 0·584 | 0·590 |
| 0·22 | 0·564 | 0·573 | 0·578 | 0·586 | 0·592 | 0·597 | 0·603 | 0·609 | 0·615 |
| 0·24 | 0·592 | 0·600 | 0·606 | 0·612 | 0·615 | 0·622 | 0·628 | 0·633 | 0·639 |
| 0·26 | 0·619 | 0·626 | 0·631 | 0·637 | 0·643 | 0·646 | 0·652 | 0·656 | 0·662 |
| 0·28 | 0·645 | 0·651 | 0·655 | 0·661 | 0·667 | 0·671 | 0·675 | 0·678 | 0·683 |
| 0·30 | 0·670 | 0·675 | 0·680 | 0·685 | 0·689 | 0·692 | 0·696 | 0·700 | 0·704 |
| 0·32 | 0·693 | 0·697 | 0·702 | 0·706 | 0·710 | 0·714 | 0·718 | 0·721 | 0·725 |
| 0·34 | 0·715 | 0·718 | 0·723 | 0·726 | 0·730 | 0·734 | 0·738 | 0·741 | 0·745 |
| 0·36 | 0·736 | 0·738 | 0·743 | 0·745 | 0·749 | 0·753 | 0·757 | 0·760 | 0·764 |
| 0·38 | 0·756 | 0·757 | 0·762 | 0·763 | 0·767 | 0·772 | 0·775 | 0·778 | 0·782 |
| 0·40 | 0·773 | 0·775 | 0·779 | 0·781 | 0·784 | 0·787 | 0·794 | 0·797 | 0·800 |
| 0·42 | 0·791 | 0·792 | 0·794 | 0·798 | 0·801 | 0·803 | 0·810 | 0·812 | 0·815 |
| 0·44 | 0·808 | 0·809 | 0·810 | 0·814 | 0·817 | 0·818 | 0·824 | 0·826 | 0·829 |
| 0·46 | 0·824 | 0·825 | 0·827 | 0·829 | 0·832 | 0·834 | 0·837 | 0·839 | 0·842 |
| 0·48 | 0·838 | 0·839 | 0·841 | 0·843 | 0·845 | 0·847 | 0·849 | 0·851 | 0·854 |
| 0·50 | 0·850 | 0·852 | 0·854 | 0·856 | 0·857 | 0·858 | 0·862 | 0·864 | 0·866 |
| 0·55 | 0·879 | 0·881 | 0·883 | 0·885 | 0·886 | 0·887 | 0·889 | 0·890 | 0·891 |
| 0·60 | 0·906 | 0·908 | 0·910 | 0·912 | 0·913 | 0·913 | 0·914 | 0·915 | 0·916 |
| 0·65 | 0·927 | 0·929 | 0·931 | 0·932 | 0·933 | 0·934 | 0·935 | 0·935 | 0·936 |
| 0·70 | 0·947 | 0·949 | 0·951 | 0·952 | 0·953 | 0·953 | 0·954 | 0·954 | 0·955 |
| 0·75 | 0·962 | 0·964 | 0·966 | 0·967 | 0·968 | 0·968 | 0·968 | 0·968 | 0·973 |
| 0·80 | 0·976 | 0·978 | 0·980 | 0·980 | 0·981 | 0·981 | 0·981 | 0·981 | 0·981 |
| 0·90 | 0·994 | 0·995 | 0·995 | 0·995 | 0·996 | 0·997 | 0·997 | 0·998 | 0·998 |

*Example.*—Given the cut-off $h = ·2$, the clearance space $s = 7$ per cent., the expansion coefficient $k = ·571$.

The losses of power from wiredrawing, &c., as shown in diagrams, figs. 1022, 1023, are represented by $\sigma$, expressed in

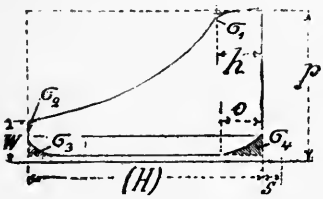



Fig. 1022.

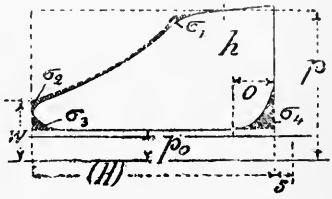



Fig. 1023.

pressure on the piston area during the whole stroke in lbs. per square inch.

$\sigma_1$ the loss due to wiredrawing or throttling the steam during admission.

$\sigma_2$ the loss due to early opening of the exhaust.

$\sigma_3$ the loss due to the back pressure of the exhaust steam.

$\sigma_4$ the loss due to compression.

$\sigma_5$ the loss due to the drop in pressure in compound engines.

$\sigma = \sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5$ = the sum of all these losses.

The loss $\sigma$, by wiredrawing increases with the lateness of the cut-off $h$ for engines with the usual valve-gears, Meyer's, Rider's, &c., and is given in Table 136.

TABLE 136.—**Values of $\sigma_1$.**

| Cut-off $h$ . . | ·05 | ·10 | ·15 | ·20 | ·30 | ·40 | ·50 | ·60 | ·70 |
|---|---|---|---|---|---|---|---|---|---|
| Without jacket . | 1·14 | 1·42 | 1·70 | 2·15 | 2·56 | 2·84 | 3·41 | 3·70 | 4·00 |
| With jacket . | ·43 | ·57 | ·71 | 1·00 | 1·14 | 1·42 | 1·70 | 2·00 | 2·13 |

TABLE 137.—**Values of $\sigma_2$ in lbs. per Square Inch.**

| Percentage of exhaust opening before end of stroke. | Without condenser. Final pressure $w$ in lbs. per sq. in. | | | | With condenser. Final press. in lbs. per sq. in. | | |
|---|---|---|---|---|---|---|---|
| | 17·64 | 29·4 | 44·1 | 58·8 | 14·7 | 29·4 | 44·1 |
| ·02 | ·000 | ·000 | ·000 | ·000 | ·000 | ·000 | ·000 |
| ·05 | ·000 | ·073 | ·147 | ·220 | ·073 | ·117 | ·147 |
| ·10 | ·043 | ·220 | ·430 | ·588 | ·294 | ·357 | ·430 |
| ·20 | — | 1·17 | 1·32 | 1·47 | ·882 | 1·17 | 1·32 |
| ·30 | — | 1·47 | 1·91 | 2·20 | — | — | — |

If the exhaust opens up 2 per cent. or less before the end of the stroke the loss is very small, some valve gears, however, will not allow of the exhaust being kept closed later than from 20 to 30 per cent. before the end of the stroke.

The values of $\sigma_2$ are given in Table 137.

TABLE 138.—**Values of Back Pressure $\sigma_3$.**

| Exhaust lead. | Without condenser. Final pressure $w$ in lbs. per sq. in. | | | | With condenser. Final press. in lbs. per sq. in. | | |
|---|---|---|---|---|---|---|---|
| $Vo$ | 18·37 | 29·4 | 44·1 | 58·8 | 14·7 | 29·4 | 44·1 |
| $Vo = a$ | ·000 | ·043 | ·147 | ·430 | ·073 | ·147 | ·294 |
| $Vo = 0{\cdot}5\,a$ | ·073 | ·117 | ·220 | ·588 | ·147 | ·730 | 1·17 |
| $Vo = 0{\cdot}2\,a$ | ·294 | ·430 | ·588 | 1·03 | ·588 | 1·17 | 1·76 |
| $Vo = 0$ | ·588 | 1·32 | 1·47 | 1·76 | 1·17 | 1·47 | 2·64 |

The values of $\sigma_3$, the back pressure or exhaust resistance caused by early closing, are dependent on the inside or exhaust lead, and the final pressure $w$, and are given in Table 138.

## Values of Compression $\sigma_4$.

TABLE 139.—**Without Condenser** ($\rho_o = 16{\cdot}4$ lbs. per sq. in.).

| Compression | Clearance space in per cent. of stroke $s$. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2% | 3% | 4% | 5% | 6% | 7% | 8% | 9% | 10% |
| 0·00 | 0 | 0 | 0 | 0 | 0 | 0 | — | — | — |
| 0·025 | ·228 | ·214 | ·209 | ·185 | ·171 | ·128 | ·114 | ·085 | ·071 |
| 0·050 | ·626 | ·551 | ·485 | ·415 | ·341 | ·271 | ·228 | ·185 | ·142 |
| 0·075 | ·925 | ·855 | ·782 | ·712 | ·640 | ·571 | ·485 | ·385 | ·285 |
| 0·10 | 1·550 | 1·38 | 1·14 | ·891 | ·792 | ·732 | ·700 | ·685 | ·670 |
| 0·15 | — | 2·70 | 2·34 | 1·96 | 1·71 | 1·44 | 1·26 | 1·06 | ·99 |
| 0·20 | — | — | 3·47 | 3·25 | 2·90 | 2·56 | 2·28 | 2·09 | 1·71 |
| 0·25 | — | — | — | 4·45 | 4·10 | 3·76 | 3·51 | 3·28 | 2·98 |
| 0·30 | — | — | — | — | 5·32 | 5·00 | 4·75 | 4·46 | 3·75 |

TABLE 140.—**With Condenser** ($\rho_o = 3{\cdot}13$ lbs. per sq. in.).

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0·00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0·025 | ·028 | ·028 | ·028 | ·028 | ·014 | ·014 | ·014 | ·014 | ·014 |
| 0·050 | ·071 | ·057 | ·043 | ·043 | ·028 | ·014 | ·014 | ·014 | ·014 |
| 0·075 | ·142 | ·128 | ·114 | ·081 | ·057 | ·043 | ·028 | ·014 | ·014 |
| 0·10 | ·284 | ·256 | ·214 | ·157 | ·128 | ·100 | ·071 | ·043 | ·028 |
| 0·15 | ·525 | ·470 | ·412 | ·341 | ·285 | ·256 | ·228 | ·209 | ·171 |
| 0·20 | ·821 | ·770 | ·670 | ·570 | ·512 | ·455 | ·400 | ·341 | ·314 |
| 0·25 | 1·10 | 1·01 | ·925 | ·810 | ·770 | ·728 | ·640 | ·527 | ·485 |
| 0·30 | 1·54 | 1·41 | 1·24 | 1·03 | ·970 | ·855 | ·810 | ·770 | ·728 |

TABLE 141.—**Values of the Cut-off $h$ with a given Final Pressure, $w$, for Clearance Spaces of 3 to 7 per cent.**

| At. ab. | $p$=8 Atmos. Absolute. | | | $p$=7 Atmos. Absolute. | | | $p$=6 Atmos. Absolute. | | | $p$=5 Atmos. Absolute. | | | $p$=4 Atmos. Absolute. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $w$ | $s$=3°/₀ | 5°/₀ | 7°/₀ | 3°/₀ | 5°/₀ | 7°/₀ | 3°/₀ | 5°/₀ | 7°/₀ | 3°/₀ | 5°/₀ | 7°/₀ | 3°/₀ | 5°/₀ | 7°/₀ |
| 0·6 | 0·047 | 0·027 | 0·012 | 0·058 | 0·040 | 0·021 | 0·073 | 0·055 | 0·037 | 0·093 | 0·076 | 0·059 | 0·124 | 0·106 | 0·090 |
| 0·7 | 0·061 | 0·042 | 0·023 | 0·073 | 0·055 | 0·037 | 0·090 | 0·072 | 0·054 | 0·114 | 0·097 | 0·080 | 0·150 | 0·134 | 0·118 |
| 0·8 | 0·073 | 0·055 | 0·037 | 0·088 | 0·070 | 0·052 | 0·107 | 0·090 | 0·072 | 0·135 | 0·118 | 0·101 | 0·176 | 0·160 | 0·144 |
| 0·9 | 0·086 | 0·068 | 0·053 | 0·103 | 0·085 | 0·067 | 0·124 | 0·107 | 0·096 | 0·155 | 0·139 | 0·123 | 0·202 | 0·186 | 0·171 |
| 1·0 | 0·098 | 0·081 | 0·064 | 0·117 | 0·100 | 0·083 | 0·141 | 0·125 | 0·108 | 0·176 | 0·160 | 0·144 | 0·229 | 0·212 | 0·197 |
| 1·2 | 0·127 | 0·107 | 0·095 | 0·147 | 0·130 | 0·113 | 0·174 | 0·160 | 0·144 | 0·217 | 0·202 | 0·183 | 0·279 | 0·265 | 0·251 |
| 1·4 | 0·150 | 0·133 | 0·117 | 0·176 | 0·160 | 0·144 | 0·210 | 0·195 | 0·179 | 0·255 | 0·244 | 0·229 | 0·337 | 0·318 | 0·305 |
| 1·6 | 0·178 | 0·160 | 0·144 | 0·205 | 0·190 | 0·174 | 0·244 | 0·230 | 0·215 | 0·299 | 0·286 | 0·272 | 0·389 | 0·370 | 0·358 |
| 1·8 | 0·202 | 0·186 | 0·171 | 0·234 | 0·220 | 0·205 | 0·279 | 0·265 | 0·251 | 0·340 | 0·328 | 0·315 | 0·434 | 0·422 | 0·412 |
| 2·0 | 0·227 | 0·212 | 0·197 | 0·265 | 0·250 | 0·235 | 0·313 | 0·300 | 0·287 | 0·382 | 0·370 | 0·358 | 0·485 | 0·475 | 0·465 |
| 2·5 | 0·292 | 0·278 | 0·264 | 0·337 | 0·325 | 0·312 | 0·399 | 0·387 | 0·375 | 0·485 | 0·475 | 0·465 | 0·614 | 0·606 | 0·600 |
| 3·0 | 0·356 | 0·343 | 0·331 | 0·411 | 0·400 | 0·390 | 0·485 | 0·475 | 0·465 | 0·588 | 0·580 | 0·572 | 0·742 | 0·737 | 0·732 |
| 3·5 | 0·420 | 0·409 | 0·398 | 0·485 | 0·475 | 0·405 | 0·571 | 0·562 | 0·554 | 0·693 | 0·685 | 0·679 | 0·871 | 0·868 | 0·862 |
| 4·0 | 0·485 | 0·475 | 0·465 | 0·558 | 0·550 | 0·541 | 0·656 | 0·650 | 0·643 | 0·794 | 0·790 | 0·786 | 1·000 | 1·000 | 1·000 |
| 4·5 | 0·549 | 0·540 | 0·531 | 0·632 | 0·625 | 0·617 | 0·742 | 0·737 | 0·731 | 0·897 | 0·893 | 0·890 | — | — | — |
| 5·0 | 0·610 | 0·600 | 0·599 | 0·705 | 0·700 | 0·695 | 0·830 | 0·821 | 0·811 | 1·000 | 1·000 | 1·000 | — | — | — |

Pressures in Atmospheres Absolute.

*Example.*—Given the final pressure $w$=1·2 atmospheres absolute, the clearance $s$=5 per cent., and the initial pressure $p$=7 atmospheres absolute, then the cut-off $h$ will=0·13.

**Values of the Final Pressure $w$ in Atmospheres Absolute for the most Economical Normal Horse-power.**

TABLE 142.—**Simple Engine.**

| $N_i$ | Non-condensing. | | | | Condensing. | | | |
|---|---|---|---|---|---|---|---|---|
| | Initial pressure $p$ in Atmospheres Absolute. | | | | | | | |
| | 4—5·5 | 6—7·5 | 8—9 | 10 | 4—5·5 | 6—7·5 | 8—9 | 10 |
| 2—5 | 2·0 | 2·0 | 2·1 | 2·2 | — | — | — | — |
| 5—10 | 1·8 | 1·8 | 1·9 | 2·1 | — | — | — | — |
| 10—50 | 1·6 | 1·7 | 1·8 | 2·0 | 0·8 | 0·9 | 1·0 | 1·1 |
| 50—100 | 1·5 | 1·6 | 1·7 | 1·9 | 0·8 | 0·9 | 1·0 | 1·1 |
| 100—200 | 1·4 | 1·5 | 1·6 | 1·8 | 0·7 | 0·8 | 0·9 | 1·0 |
| 200 and upwards. | 1·3 | 1·4 | 1·5 | 1·7 | 0·7 | 0·8 | 0·9 | 1·0 |

TABLE 142A.—**Compound Engine**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10—50 | — | — | 1·6 | 1·7 | 0·7 | 0·8 | 0·9 | 1·9 |
| 50—100 | — | — | 1·5 | 1·6 | 0·7 | 0·8 | 0·8 | 0·9 |
| 100—500 | — | — | 1·4 | 1·5 | 0·6 | 0·7 | 0·8 | 0·9 |
| 500 and upwards. | — | — | 1·3 | 1·4 | 0·5 | 0·6 | 0 7 | 0·8 |

*Example.*—The best final pressure $w$ for a simple condensing engine with $N_i = 150$ H.P., and 7 atmospheres absolute is from the Table ·8 atmospheres absolute, the corresponding cut-off from Table 133, with 7 per cent. clearance space, gives ·052.

The losses $\sigma_4$ by compression given in Tables 139, 140, are dependent on the length of the compression period $o$, and the back pressure $P_c$. The clearance space depends on the kind of valve-gear used. See Table 33.

Clearance space $s$ expressed in terms of length of stroke, for H = 1.

TABLE 143.

| Kind of valve-gear used. | | | |
|---|---|---|---|
| Ordinary valve-gear. | Divided valves and piston valves. | Mushroom valves. | Corliss valves. |
| 0·06 – 0·08 | 0·03 – 0·06 | 0·04 | 0·025 |

The above values for $s$ are for ordinary piston speeds. For very quick running engines with higher piston speed, the clearance space may be double the value given above.

A coefficient approximately proportional to the efficiency of an engine may be found by dividing the mean pressure (taken from the indicator diagram) by the final pressure (absolute) $\frac{P_m}{w}$. For example, an engine giving a mean pressure of 37, and a final pressure absolute of 23·7, gives this coefficient $\frac{37}{23{\cdot}7} = 1{\cdot}56$. In many engines this coefficient is greater than 2, but has hardly reached 3.

The water per IHP per hour, can be approximated from the coefficient thus obtained. Divide the undermentioned constants by the coefficient, and the quotient will give the water per IHP per hour, in lbs.

When the final pressure is about 5 lbs. *below* the atmosphere, the constant = 36; with a final pressure 15 lbs. *above* the atmosphere, the constant = 34; when final pressure is 45 lbs. above atmosphere the constant = 32.

Either of these divided by the coefficient will give the quantity of water per IHP per hour, very nearly, *exclusive* of the losses by clearance and condensation, jacket, &c., and the gain by compression.

Take as an example the engine before referred to which had a final pressure of 9 lbs. above the atmosphere, and use corresponding constant 34. $\frac{34}{1{\cdot}56} = 21{\cdot}7$ lbs., add $\frac{1}{10}$ for clearance and loss exclusive of jacket = 23·87 lbs. per 1 H.P. per hour. The water measured was 24·1 lbs. per 1 H.P. per hour, which shows how near the formula is.

---

Let $l = l' + l''$ resistance in non-condensing engine running light;
$l = l'_c + l''_c$ „ condensing „ „
$\mu$ coefficient of additional friction for single cylinder engine.
$\mu_2$ „ „ „ for double „ „

The effective power for single cylinder $\frac{Qc\,(P_m - l)}{33000\,(l + \mu)}$.

„ „ for double cylinder $\frac{Qc\,(P_m - l)}{33000\,(1 + \mu_2)}$.

TABLE 144.

| D | 8 | 16 | 24 | 32 | 14 |
|---|---|---|---|---|---|
| $l''$ | 1·86 | 1·00 | ·571 | ·428 | ·285 |
| $l''_c$ | 3·14 | 1·57 | 1·00 | ·715 | ·571 |
| $\mu$ | ·18 | ·14 | ·12 | ·10 | ·08 |
| $\mu_2$ | ·20 | ·16 | ·13 | ·11 | ·10 |

TABLE 145.

| $p$ | 59 | 88 | 118 |
|---|---|---|---|
| $l'$ | 1·14 | 1·43 | 1·71 |
| $l'$ | 1·71 | 2·00 | 2·28 |

$p$ = pressure in lbs. per sq. inch.

By very careful management the coefficient $\mu$ may be reduced by 30%.

### Calculation of the Power of Compound Engines.

The power of a compound engine should be the same as if the total expansion had been carried out in one large cylinder, the expression for the total expansion being

$$\frac{\text{initial absolute pressure}}{\text{final absolute pressure}} = \frac{P}{w}.$$

In figures 1024, 1025,

$h$ = the period of admission.
$s$ = the clearance.
$w$ = the final pressure.
$d$ = the diameter of the high-pressure cylinder.
$h'$, $s'$, $w'$, = as above for the high-pressure cylinder.
D = diameter of low-pressure cylinder.
$h''$, $s''$, $w''$ = as above for the low-pressure cylinder.
$\frac{V}{v}$ = the ratio of the cylinder volumes.
Q = the surface of the low-pressure piston.
$h_i$ = the ideal admission reduced the low-pressure cylinder volume corresponding to the total expansion.
$s = \frac{s''}{\frac{V}{v}}$ for determining the mean pressure for the ideal value of the clearance space.

Then, taking the stroke of both cylinders to be the same,

Taking no account of the clearance space.

$$\frac{V}{v \times h'} = \frac{P}{W''} = \frac{1}{h'} \times \frac{1}{h''}.$$

Allowing for the clearance space.

$$\frac{V \times (l + s'')}{v \times (h' + s')} = \frac{P}{W''} = \frac{1}{h' + s'} \times \frac{1}{h'' + s''}.$$

*Example.*—To calculate the nominal power of a compound condensing engine.

| | | |
|---|---|---|
| Diameter of high-pressure cylinder . . | $d$ | $15\frac{3}{4}''$. |
| Diameter of low-pressure cylinder . | D | $24''$. |
| Stroke of both . . . . . | H | $27\frac{1}{2}''$. |

Ratio of cylinder volumes . . . $\frac{V}{v} = 2{\cdot}35.$

Revolutions per minute . . . . $n = 75.$
Initial pressure absolute . . . P $= 103.$
Clearance space of low-pressure cylinder $s''$ = about 5 per cent.
Final pressure $w = w''$ from Table 142A, $w = 11{\cdot}76.$

Ideal clearance space $s_i = \frac{0{\cdot}05}{2{\cdot}35}$ . . $s_i = 0{\cdot}02.$

Ideal admission from Table 141 . . $h_i = 0{\cdot}1.$
Coefficient of expansion from Table 135 . $k = 0{\cdot}356.$
Back pressure and loss of work . $P_o + \sigma = 7.$
Then the mean pressure $P_m = kp - (P_o + \sigma) = {\cdot}356 \times 103 - 7 = 30{\cdot}7$ lbs. per square inch.

The piston speed in feet per minute, $c = 344.$

the effective area of the piston, $Q = 446$ square inches ;

the ideal indicated horse-power $N_i$,

$$= \frac{Qc\ P_m}{33000} = \frac{446 \times 344 \times 30{\cdot}7}{33000} = \text{approximately } 140.$$

The friction coefficient $\mu_e = 0{\cdot}16$ (Table 144).

The resistance of the engine when running empty (see Tables 144, 145). $l = l'_e = 2{\cdot}14 + 1{\cdot}56 = 3{\cdot}7$ ;

then the effective horse-power $N_e$

$$= \frac{Qc\ (P_m - l)}{33000\ (1 + \mu_e)} = \frac{446 \times 344\ (3017 - 3{\cdot}7)}{33000\ (1 + 0{\cdot}16)} = \text{nearly } 103.$$

The admission or cut-off in the high-pressure cylinder is determined as follows :—

The total expansion being $\frac{P}{w''} = \frac{103}{11{\cdot}76} = 8{\cdot}75.$

If now $s' = s'' = 0{\cdot}05,$

then $$\frac{V\ (1 + s'')}{v\ (h' + s')} = \frac{2{\cdot}35 \times 1{\cdot}05}{h' + 0{\cdot}05} = 8{\cdot}75 ;$$

therefore $$h' = \frac{2{\cdot}35 \times 1{\cdot}05}{8{\cdot}75} - 0{\cdot}05 = 0{\cdot}23.$$

The final pressure in the high-pressure cylinder will be

$$w' = \frac{(h' + s')\,P}{1 + s'} = \frac{(0{\cdot}23 + 0{\cdot}05) \times 103}{1{\cdot}05} = 27{\cdot}4$$

and we shall have the mean pressure in the low-pressure cylinder, taking the drop of pressure as 5·88,

$$p'' = 27{\cdot}4 - 5{\cdot}88 = 21{\cdot}52$$

then it follows that

$$h'' = \frac{w''\,(1 + s'')}{p''} - s'' = \frac{11{\cdot}76 \times 1{\cdot}05}{21{\cdot}52} - 0{\cdot}05 = {\cdot}525 \text{ sq. } {\cdot}55.$$

If the horse-power is given, and the diameter of the low-pressure cylinder is required, it can be approximated in the following manner:

From Table 142, $p$ is selected, $P_m$ from Table 146, and $c$ from Table 147,

$$\text{then } Q = \frac{33000 \times N_i}{c\ P_m}.$$

TABLE 146.

| | Initial pressure in lbs. per square inch. | | | | | | |
|---|---|---|---|---|---|---|---|
| $P_m$ = | 59 | 74 | 88 | 103 | 118 | 132 | 147 |
| | 23·5 | 26·5 | 31 | 35·2 | 38·2 | 41 | 45·2 |

**Indicator Diagrams for the Normal Horse-Power for the Compound Engines given in Table 147.**

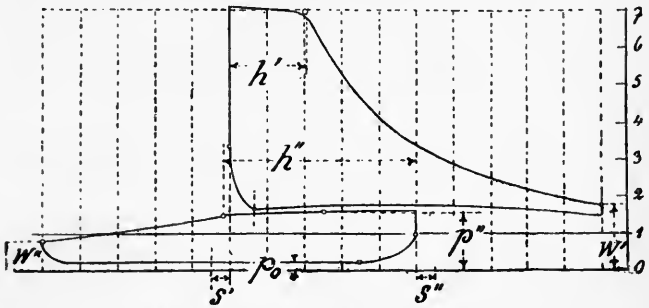



Fig. 1024.—Pressures in atmospheres absolute.

$$w' = \frac{(h' + s')\,p}{1 + s'}\,; \quad w'' = \frac{(h'' + s'')\,p''}{1 + s''}\,;$$

$$h' = \frac{w'\,(1 + s')}{p} - s'\,; \quad h'' = \frac{w''\,(1 + s'')}{p''} - s''\,;$$

$w' - p'' =$ the drop in the pressure.

The power in both cylinders is nearly equal.

**Indicator Diagram for the Maximum Horse-Power for the Compound Engines given in Table 147.**

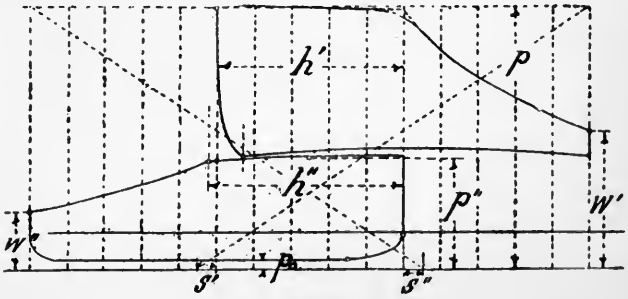



Fig. 1025.

TABLE 147.—**Compound Condensing Engines, 103 lbs. Absolute Pressure per square inch.**

| Stroke. | High-Pressure Cylinder | Low-Pressure Cylinder | | | | | | | | | | | | | | Per I.H.P. per hour. | | Injection Water in gals. per hour. | Maximum power effective. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | $d$ | D | $\frac{V}{v}$ | $n$ | $c$ | Q | $w$ | $N_i$ | $k$ | $P_o$ | O | $P_m$ | N | $N_e$ | | Water in lbs. | Coal in lbs. | | $N_e$ | Water per $N_i$ per I.H.P. per hour in lbs. |
| 20 | $11\frac{3}{4}$ | 18 | 2·3 | 90 | 300 | 254 | 11·76 | ·10 | ·356 | 3·1 | 2·7 | 30·7 | 65 | 47 | 45 | 18·66 | 2·86 | 2500 | 68 | 25·2 |
| 24 | $13\frac{3}{4}$ | 21 | 2·3 | 80 | 320 | 346 | 11·76 | ·10 | ·356 | 3·1 | 2·7 | 30·7 | 96 | 71 | 70 | 18·07 | 2·77 | 3525 | 107 | 23·8 |
| 28 | $15\frac{3}{4}$ | 24 | 2·3 | 75 | 350 | 452 | 11·76 | ·10 | ·356 | 3·1 | 2·7 | 30·7 | 140 | 106 | 100 | 17·62 | 2·64 | 5000 | 151 | 22·5 |
| 32 | $17\frac{1}{2}$ | 27 | 2·35 | 70 | 370 | 572 | 11 | ·09 | ·33 | 3·1 | 2·7 | 28·1 | 174 | 132 | 130 | 16·95 | 2·40 | 6025 | 208 | 21·2 |
| 36 | 20 | $30\frac{1}{2}$ | 2·35 | 67 | 400 | 730 | 11 | ·09 | ·33 | 3·1 | 2·7 | 28·1 | 235 | 179 | 175 | 16·29 | 2·20 | 7700 | 280 | 19·8 |
| 40 | $21\frac{3}{4}$ | $33\frac{1}{2}$ | 2·37 | 65 | 430 | 881 | 11 | ·09 | ·33 | 3·1 | 2·7 | 28·1 | 308 | 237 | 230 | 15·63 | 2·09 | 9500 | 374 | 18·7 |

The high-pressure cylinder has variable cut-off from ·0 to ·5, compression $0' = 1$.
The low-pressure cylinder has fixed cut-off at ·5, compression $0'' = 2{\cdot}56$.

$\frac{V}{v}$ = ratio of the cylinder volumes; Q = surface of low-pressure piston in square inches.

$s_i = \frac{s'}{\frac{V}{v}}$ = ideal clearance space; $h_i$ = ideal cut-off; $w$ = final pressure absolute.

## SECTION XI.

### THE EFFECT OF THE INERTIA OF THE RECIPROCATING PARTS OF A STEAM ENGINE.

The effect of the inertia of the reciprocating parts of an engine especially with high speeds may have a great influence on the smoothness of the running.* The effect of inertia has been ignored by engine makers, it was pointed out in a paper on the Allen engine by Mr. C. T. Porter in 1868,† with special reference to the change in direction of the pressure on the crank-pins of steam engines at certain parts of the stroke.

Let P = the weight of the reciprocating mass in lbs.
$f$ = the surface of the piston in square inches.

The approximate proportion of weight to piston surface will be $\frac{P}{f} = 3{\cdot}98$ for horizontal non-condensing engines, $\frac{P}{f} = 4{\cdot}27$ for horizontal condensing engines. In the Allen engine above alluded to, the weight of the reciprocating parts was 470 lbs., and the piston surface 113 square inches; this gives the proportion P to $f$ as 4·16 to 1).

H = stroke in feet.
$r$ = Crank radius in feet.
$n$ = Revolutions per minute.

$v = \frac{2r\pi n}{60}$ = the average speed of the crank pin in feet per second.

#### (a.) The Connecting-Rod of Infinite Length.

The pull on the connecting-rod necessary to overcome the inertia of the reciprocating parts is equal to the horizontal component of the acceleration of the crank pin multiplied by the mass moved; at the dead point this component is equal to the total acceleration of the crank pin towards the centre of the crank shaft, *i.e.*, to $\frac{v^2}{r}$.

* Radinger Maschinen mit höher Kolbengeschwindigkeit.
† Institution of Mechanical Engineers' Proceedings, April, 1868.

The total drag on the connecting-rod at the beginning of the stroke is therefore $\frac{Pv^2}{gr}$, hence the pressure on unit surface of the face of the piston necessary to neutralize this $-\frac{Pv^2}{grf} = q1$. At the highest point of the crank $q = 0$, since at that point there will be no further pressure expended in producing acceleration of the reciprocating parts, as the piston has attained the same speed as the crank pin. At intermediate points $q = q_1 \cos.\ \omega$, where $\omega$ = the angle swept out by the crank pin from the dead point.

It is easy to represent graphically the retarding or accelerating forces acting on the piston due to the inertia of the reciprocating parts, as in this case the motion of the piston is simple harmonic, *i.e.*,

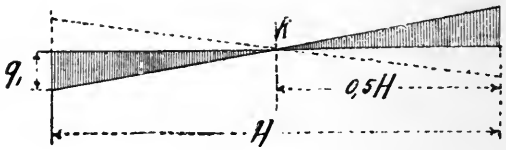



Fig. 1026.

the acceleration and therefore the accelerating force is proportional to the distance of the face of the piston from the centre of its path. If we plot out a curve where the ordinates are pressures and the abscissæ the corresponding position of the piston, we get a straight line which cuts the axis of abscissæ at the point $k$ where $q = 0$.

*Example.* To determine the effect of the inertia of the moving parts of an engine where the diameter of the piston D = 16″ and the stroke H = 28″, $n = 100$.

$$\text{By our formula } \frac{P}{f} = 3{\cdot}98.$$

$$\therefore P = 3{\cdot}98 \times 16^2 \times \frac{\pi}{4}$$

$$= 798 \text{ lbs.}$$

$$v = \frac{2\pi \times 100 \times \frac{7}{6}}{60}$$

$$= 12{\cdot}2 \text{ feet per second.}$$

The pressure per square inch on the face of the piston necessary to move the reciprocating masses at the beginning of the stroke

$$= \frac{Pv^2}{grf} = \frac{798 \times (12{\cdot}2)^2}{32{\cdot}2 \times \frac{7}{6} \times 16^2 \times \frac{\pi}{4}} = 49{\cdot}4 \text{ lbs.}$$

The pressure diminishes towards the middle of the stroke, where it vanishes, the inertia of the reciprocating masses then assists the steam pressure, at the end of the stroke this pressure is 49·4 lbs. per square inch.

In order, therefore, that the pressure on the crank pin may be constant, we must have high pressure at the beginning of the stroke, and low pressure at the end of the stroke. The expansion of the steam does this, and compensates to a great extent for the forces introduced by the inertia of the reciprocating parts. If the compensation is not sufficient the momentum of the fly-wheel must help to drag the piston to its full speed at the beginning of the stroke, and oppose its motion at the end. Consequently, there is a change from extension to compression in the connecting-rod and a knock ensues which if neglected soon causes trouble. To remedy this, the steam must be cushioned at the end of the stroke by closing the exhaust early. The energy possessed by the moving reciprocating masses is thus employed in compressing the steam, and is restored at the beginning of the stroke where it is wanted.

### (b.) With Connecting-Rod of Finite Length.

Let L = the length of the connecting-rod.

$\frac{r}{L}$ = ratio of crank radius to length of connecting-rod.

$q$ = accelerating pressure in lbs. per square inch of the piston face necessary to overcome or retard the inertia of the moving parts.

$\omega$ = the angle swept out by the crank arm.

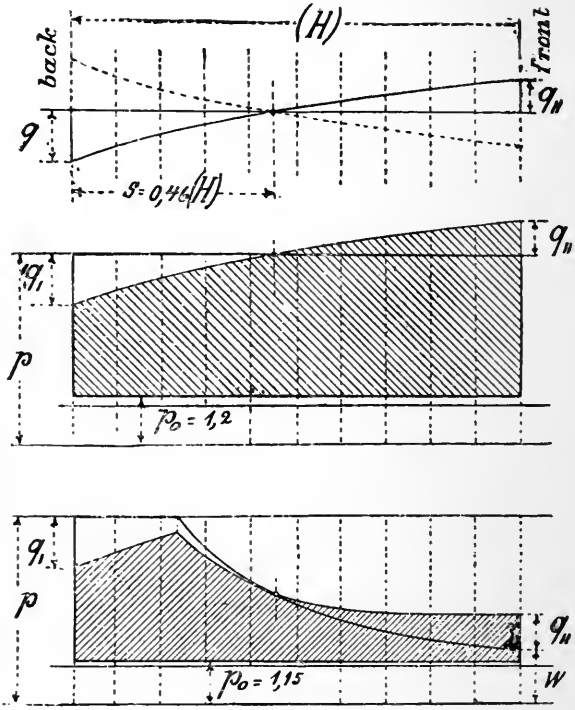
Then $q = \frac{P v^2}{grf}\left(\text{cos. } \omega + \frac{r}{L} \text{ cos. } 2\omega\right)$ approximately. At the dead point for the outstroke $q_1 = \frac{P v^2}{grf}\left(1 + \frac{r}{L}\right)$ and opposes the steam pressure at the dead point at the end of the stroke $q_2 = \frac{P v^2}{grf}\left(1 - \frac{r}{L}\right)$ and assists the steam pressure. The space S, travelled by the piston when the crank arm has turned through an angle $\omega$ is given by

$$S = r\left(1 - \text{cos. } \omega + \frac{1}{2}\frac{r}{L}\text{ sin.}^2\,\omega\right) \text{ approximately.}$$

This distance S is best calculated by graphical construction.

The case of $\frac{r}{L} = \frac{1}{5}$ is shown in fig. 1027.

For all values of S the ordinates are plotted out.




Figs. 1027—1029.

*Outstroke*—

$$\omega = 0\,; \qquad q_1 = \frac{6}{5}\,\frac{P v^2}{grf}\,;$$

$$\omega = 180^\circ\,; \quad q_2 = -\frac{4}{5}\,\frac{P v^2}{grf}.$$

*Return stroke* (steam pressure acting in opposite direction)—

$$\omega = 180^\circ\,; \qquad q_1 = \frac{4}{5}\,\frac{P v^2}{grf}\,;$$

$$\omega = 360^\circ\,; \quad q_2 = -\frac{6}{5}\,\frac{P v^2}{grf}\,;$$

when $\omega = 79°$; $s = 0{\cdot}46$ H; $q = 0$.
$\omega = 259°$; $s = 0{\cdot}54$ H; $q = 0$.

*Example.*—Take an engine where D = 16″, H = 28″, $n = 100$; L = 5 $r$.

Then as in preceding example—

P = 798 lbs. $v$ = 12·2 feet per sec.

$$q_1 = \frac{6}{5} \times 49{\cdot}4 = 59{\cdot}3.$$

$$q_2 = \frac{4}{5} \times 49{\cdot}4 = 39{\cdot}5.$$

Suppose the steam pressure to be 140 lbs. per square inch at the beginning of the stroke and to be expanded five times; the pressure at the end of the stroke would be $\frac{140 + 15}{5} - 15 = 16$ lbs. per square inch approximately.

The pressure on the crank pin at the beginning of the stroke would be $= (140 - 59{\cdot}3)f = 80{\cdot}7f$, and at the end of the stroke it would be $= (16 + 39{\cdot}5)f = 55{\cdot}5f$. If the steam had been expanded 2·8 times, the pressure at the end of the stroke would equal the pressure at the beginning of the stroke. Had there been no expansion, the pressures would have been $80{\cdot}7f$ at the beginning and $179{\cdot}5f$ at the end of the stroke. The pressure on the crank pin at the end of the stroke would thus have been more than double the pressure at the beginning.

The values of $q$ are plotted out in fig. 1027. In fig. 1028 the pressure on the crank pin is represented graphically when the steam pressure is maintained constant throughout the stroke. The shaded area above the line is exactly equal in area to the unshaded area below the line which could have been predicted since the energy communicated to the reciprocating masses at the beginning of the stroke is equal to the energy given up by them at the end of the stroke.

In fig. 1029, we see the influence of the reciprocating masses on the pressure on the crank pin for the same engine when the cut-off is at 0·4 of the stroke. From the diagram it is apparent that with quick-running engines working with late cut-off, the pressure on the crank pin due to the inertia of the reciprocating masses, and the pressure of the steam combined at the end of the stroke far exceeds the admission pressure. Cushioning the steam gets over this, and it seems at first sight to be most advantageous to have the compression at the dead point = the final steam pressure + the pressure due to

the reciprocating masses; *i.e.*, $c = w + q_2$ (fig. 1030). Thus the admission pressure can be easily calculated.

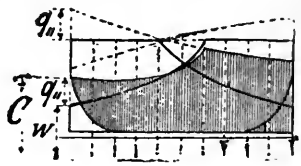



Fig. 1030.

In order to carry out a high degree of expansion, a high speed of piston is necessary, for the inertia of the reciprocating parts in this case compensates for the extreme variation in steam pressure consequent upon an early cut-off. If we consider smoothness of running only, the engine should be run so fast that the driving force produced by the highest pressure of the steam cannot exceed the inertia of the reciprocating parts, then a knock upon the centres becomes impossible.

The usual small compression given in slow-going engines causes nearly the whole of the initial pressure to act suddenly on the piston, and this makes the connecting-rod knock on the crank pin.

The author holds that it is of the very greatest importance to have smooth and noiseless running, and this is only possible with the help of compression. In engines with double valve gear and large clearance spaces, it is difficult to obtain sufficient compression, most makers avoiding the large valves and eccentrics necessarily required.

As a general rule, *always endeavour to have the compression in a non-condensing engine at least equal to half the admission pressure and in a condensing engine as much as possible.*

We can employ the standard proportions given on page 181. The valve gear, page 184, can only be used with divided valves (*i.e.*, in two short valves, one at each end of the cylinder for short ports) with small clearance space. The end pressure due to compression $C = \frac{(o + s)}{s} P_0$ can be determined by the use of the Tables 148 and 149, when the valve $s$ of the clearance space, and the portion of the stroke during which compression takes place, are known. The pressures in the Tables are given in atmospheres. Non-condensing engines [$P_0 = 1{\cdot}15$], condensing engines [$P_0 = 0{\cdot}2$].

$$\text{Value of } q = \frac{P v^2}{grf} \text{ (atmos.)}$$

TABLE 148.—**Pressure due to Compression in Absolute Atmospheres for Non-Condensing Engines, $P_0 = 1{\cdot}15$ At. Abs.**

| Compression period. | Clearance space $s$ in per cent. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| ·00 | 1·15 | 1·15 | 1·15 | 1·15 | 1·15 | 1·15 | 1·15 | 1·15 | 1·15 |
| ·025 | 2·55 | 2·10 | 1·87 | 1·73 | 1·63 | 1·56 | 1·50 | 1·47 | 1·44 |
| ·050 | 4·00 | 3·06 | 2·59 | 2·30 | 2·11 | 1·97 | 1·87 | 1·78 | 1·72 |
| ·075 | 5·46 | 4·03 | 3·31 | 2·87 | 2·57 | 2·38 | 2·28 | 2·11 | 2·01 |
| ·100 | 6·90 | 4·90 | 4·03 | 3·45 | 3·07 | 2·79 | 2·59 | 2·42 | 2·30 |
| ·150 | — | 6·90 | 5·46 | 4·60 | 4·00 | 3·60 | 3·31 | 3·06 | 2·87 |
| ·200 | — | — | 6·90 | 5·75 | 4·98 | 4·43 | 4·03 | 3·70 | 3·45 |
| ·250 | — | — | — | 6·90 | 5·95 | 5·29 | 4·74 | 4·34 | 4·02 |
| ·300 | — | — | — | — | 6·90 | 6·07 | 5·46 | 4·98 | 4·60 |

TABLE 149.—**For Condensing Engines $P_0 = ·2$.**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ·00 | ·20 | ·20 | ·20 | ·20 | ·20 | ·20 | ·20 | ·20 | ·20 |
| ·025 | ·45 | ·37 | ·33 | ·30 | ·28 | ·27 | ·26 | ·26 | ·25 |
| ·050 | ·70 | ·53 | ·45 | ·40 | ·37 | ·34 | ·33 | ·31 | ·30 |
| ·075 | ·95 | ·70 | ·57 | ·50 | ·45 | ·41 | ·38 | ·37 | ·35 |
| ·100 | 1·20 | ·86 | ·70 | ·60 | ·53 | ·48 | ·45 | ·42 | ·40 |
| ·150 | 1·70 | 1·20 | ·95 | ·80 | ·70 | ·63 | ·57 | ·53 | ·50 |
| ·200 | 2·20 | 1·53 | 1·20 | 1·00 | ·86 | ·77 | ·70 | ·64 | ·60 |
| ·250 | 2·70 | 1·86 | 1·45 | 1·20 | 1·03 | ·97 | ·82 | ·75 | ·70 |
| ·300 | 3·20 | 2·20 | 1·70 | 1·40 | 1·20 | 1·05 | ·95 | ·86 | ·80 |

The pressure of the compression C rises to a height which may be obtained by the formula

$$C = \frac{(o + s)}{s} P_0$$

and can be taken from the above tables for any given per-centage of clearance.

TABLE 150.—**Values of $\frac{Pv^2}{rgf}$ in Atmospheres.**

| Stroke in inches. | Diam. of piston in inches. | Revolutions per minute $n$. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| H | D | 50 | 75 | 100 | 150 | 200 | 300 | 400 | 500 |
| 6 | 4 | ·04 | ·08 | ·15 | ·35 | ·60 | 1·40 | 2·50 | 4·00 |
| 12 | 8 | ·10 | ·21 | ·40 | ·90 | 1·60 | 3·50 | — | — |
| 20 | 12 | ·18 | ·42 | ·70 | 1·50 | 3·00 | — | — | — |
| 28 | 16 | ·27 | ·60 | 1·00 | 2·50 | 4·30 | — | — | — |
| 36 | 20 | ·34 | ·75 | 1·30 | 3·00 | 5·40 | — | — | — |
| 44 | 24 | ·40 | ·90 | 1·60 | 3·50 | — | — | — | — |
| 48 | 28 | ·45 | 1·05 | 1·80 | 4·00 | — | — | — | — |
| 56 | 32 | ·50 | 1·20 | 2·10 | 4·70 | — | — | — | — |
| 64 | 36 | ·60 | 1·35 | 2·40 | 5·40 | — | — | — | — |
| 72 | 40 | ·70 | 1·50 | 2·70 | 6·00 | — | — | — | — |

Unit to calculate with $\frac{Pv^2}{grf} \times \frac{1}{14{\cdot}7} = \frac{4\pi^2 n^2 H}{180 \times 32{\cdot}2 \times 14{\cdot}7} =$ ·0000463 $n^2$ H in atmospheres.

·0000463 × 14·7 $n^2$ H = ·000681 $n^2$ H in lbs. per square inch.

*Example.*

Let H = 48″,
D = 28″,
$n = 150$, $\frac{r}{L} = \frac{1}{5}$.

By the table $\frac{Pv^2}{grf} = 4{\cdot}15$ atmos.

Thus $q_1 = 4{\cdot}15 \times \frac{6}{5} = 4{\cdot}98$,

$q_2 = 4{\cdot}15 \times \frac{4}{5} = 3{\cdot}32$.

Initial pressure $p = 7$ atmos.
$h =$ cut-off at 0·2.
$s = 6\%$ clearance.

This gives the pressure diagram, fig. 1031. The part shaded

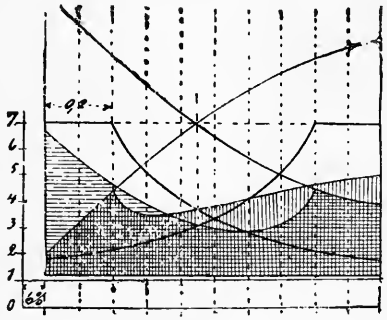



Fig. 1031.

vertically for the outstroke, and that shaded horizontally for the back-stroke.

# SECTION XII.

## FRICTION BRAKE, DYNAMOMETER.

In making trials of small engines, a friction brake is used to absorb the power during the trial. The original friction brake, fig. 1032, is due to Prony. A pair of wooden clamps, to one of which a lever $l$ is fixed, are bolted together, fig. 1032, and nip the shaft to which they are applied with more or less pressure according to the tightness of the bolts; the shaft being run in the direction of the arrow, tends by friction between the clamps and shaft to raise the weight G; if the shaft runs uniformly and the belts are adjusted so as just to keep the weight balanced, the effect is very nearly the same as if the work done was that of raising the weight continuously at the speed G would move if allowed to run with the shaft.

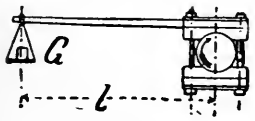


Fig. 1032.

Let G = the weight required in lbs.
$l$ = the length of the lever in feet.
$n$ = the revolutions per minute, so the "brake horse power" given out by the machine will be

$$\text{B HP} = \text{G} \times \frac{2\pi \times n \times l}{33000}$$

and G for any required load will $= \dfrac{33000\ (\text{B HP})}{2\pi \times n \times l}$.

This form of brake is still used in special cases, but the more modern form of rope brake, fig. 1033, is now much used. The rope R is spliced or seized together at one end, and passed through the "bight" as in the figure; to the upper a spring balance is hooked, the balance itself being hung from a firm support; to the other end are attached the weights necessary to give the required load. The rope is kept in its place by blocks of wood $b,b$; a small block of wood $c$, is inserted to keep the rope from nipping the other part which is on the wheel. If required for long runs, the wheel is made with

deep flanges P, and water is run in to keep it cool. The calculation is the same as for the Prony brake, taking the length of $l$ from the centre of the shaft S to the centre of the rope; but in measuring the

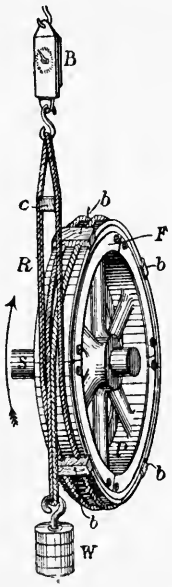



Fig 1033.

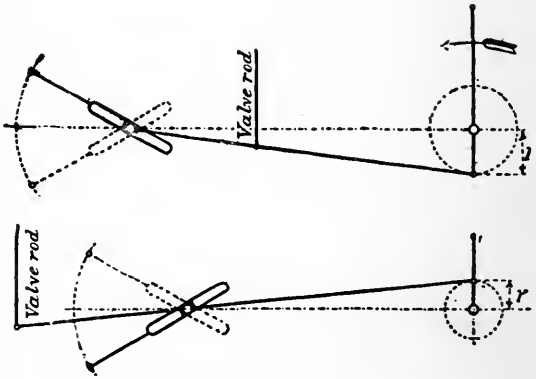
work done, frequent readings of the spring balance must be taken and subtracted from the weight to give the time load lifted. These brakes work very well, require but little attention and are fairly reliable.

# SECTION XIII.

## SUNDRY DETAILS.

### Diagrams of Special Reversing Gears.

In addition to those already shown on page 224, the diagrams below show the principle of some special reversing gears that are sometimes used for marine and other engines.*




Figs. 1034, 1035.—Reversing gear by Hackworth.

* "Zeitschrift der deutsch Ingenieur," 1885, page 949.

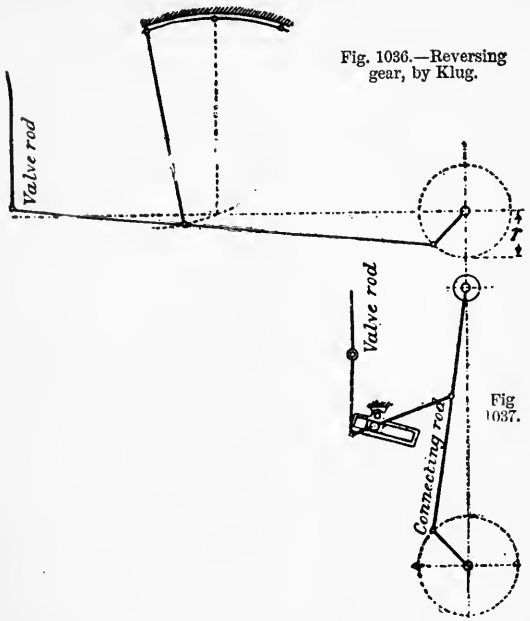
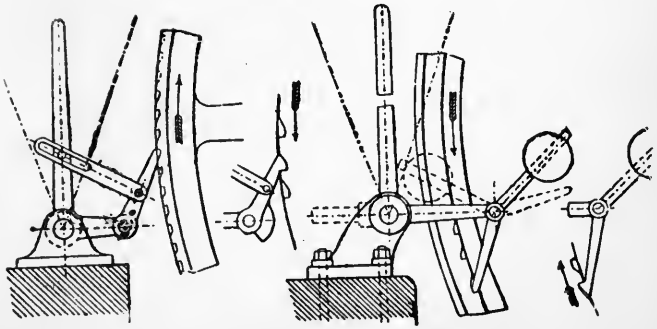



Fig. 1036.—Reversing gear, by Klug.

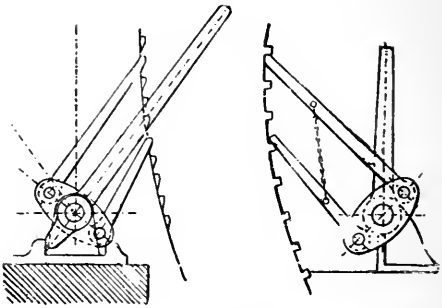
Fig 1037.

Fig. 1037.—Reversing gear, by Joy.

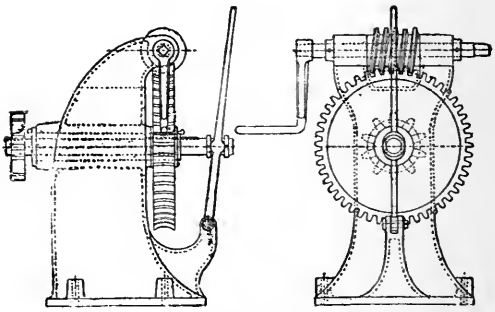
## Barring Apparatus.



Figs. 1039, 1040.—Simple lever action.



Figs. 1041, 1042.—Double lever action.



Figs. 1043, 1044.—Worm and worm-wheel.

## TABLE 151.—Particulars of Bolts.

| Diameter of bolts in inches. | No. of threads per inch. | Diameter at bottom of thread. Inches. | Area at bottom of thread in sq. inches. |
|---|---|---|---|
| $\frac{3}{8}$ | 16 | ·295 | ·0683 |
| $\frac{7}{16}$ | 14 | ·346 | ·0942 |
| $\frac{1}{2}$ | 12 | ·393 | ·1213 |
| $\frac{5}{8}$ | 11 | ·508 | ·2027 |
| $\frac{3}{4}$ | 10 | ·622 | ·3039 |
| $\frac{7}{8}$ | 9 | ·733 | ·4230 |
| 1 | 8 | ·840 | ·5542 |
| $1\frac{1}{8}$ | 7 | ·942 | ·6969 |
| $1\frac{1}{4}$ | 7 | 1·070 | ·8992 |
| $1\frac{3}{8}$ | 6 | 1·161 | 1·0569 |
| $1\frac{1}{2}$ | 6 | 1·287 | 1·2999 |
| $1\frac{5}{8}$ | 5 | 1·369 | 1·4210 |
| $1\frac{3}{4}$ | 5 | 1·494 | 1·7530 |
| 2 | $4\frac{1}{2}$ | 1·715 | 2·3087 |
| $2\frac{1}{4}$ | 4 | 1·930 | 2·9241 |
| $2\frac{3}{8}$ | 4 | 2·05 | 3·316 |
| $2\frac{1}{2}$ | 4 | 2·180 | 3·7311 |
| $2\frac{3}{4}$ | $3\frac{1}{2}$ | 2·384 | 4·464 |
| 3 | $3\frac{1}{2}$ | 2·634 | 5·450 |
| $3\frac{1}{4}$ | $3\frac{1}{4}$ | 2·855 | 6·402 |
| $3\frac{1}{2}$ | $3\frac{1}{4}$ | 3·105 | 7·563 |
| $3\frac{3}{4}$ | 3 | 3·323 | 8·673 |
| 4 | 3 | 3·573 | 10·027 |
| $4\frac{1}{4}$ | $2\frac{7}{8}$ | 3·804 | 11·368 |
| $4\frac{1}{2}$ | $2\frac{7}{8}$ | 4·054 | 12·908 |
| $4\frac{3}{4}$ | $2\frac{3}{4}$ | 4·284 | 14·404 |
| 5 | $2\frac{3}{4}$ | 4·534 | 16·146 |
| $5\frac{1}{4}$ | $2\frac{5}{8}$ | 4·762 | 17·810 |
| $5\frac{1}{2}$ | $2\frac{5}{8}$ | 5·012 | 19·72 |
| $5\frac{3}{4}$ | $2\frac{1}{2}$ | 5·239 | 21·57 |
| 6 | $2\frac{1}{2}$ | 5·489 | 23·64 |

All Dimensions are given in Inches.

# SECTION XIV.

## BOILERS.

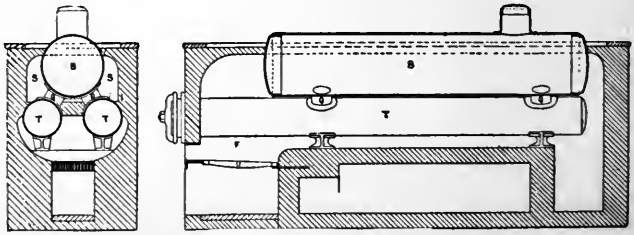
In the following pages (416 to 441), particulars of the most usual types of boilers will be found, together with figures showing their general construction.

### Elephant or French Boiler.

Figs. 1045, 1046, show this type of boiler, which has been largely used in France and occasionally in England; the table gives the general proportions.

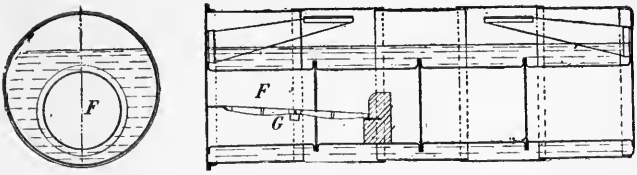
Table 152.—**Dimensions of Elephant Boilers.**

| | | | | | | |
|---|---|---|---|---|---|---|
| Nominal H.P. . . . . | 10 | 12 | 15 | 20 | 25 | 30 |
| Length of boiler in feet . . . | 14 | 16 | 18 | 23½ | 28 | 30 |
| Diameter of heaters, or "bouilleurs," in inches . . . . . | 18 | 19 | 20½ | 21½ | 23 | 24 |
| Diameter of shell in inches . . | 30 | 32 | 34 | 36 | 38 | 40 |
| Approximate heating surface in sq. ft. | 169 | 203 | 254 | 338 | 422 | 507 |




Figs. 1045, 1046.—Elephant Boiler.

## Cornish Boilers.




Figs. 1047, 1048.

This type, together with the double flued or Lancashire boiler, fig. 1053, is perhaps more largely used on land than any other type for supplying steam for steam-engines, or general manufacturing purposes.

The Tables 153 to 166, with the exception of table 161, give the dimensions of these boilers by different English makers.

TABLE 153.—**Dimensions of Cornish Boilers made by Messrs. Marshall, Sons & Co. Limited.**

| Nominal H.P. | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 25 |
|---|---|---|---|---|---|---|---|---|---|
| Dia. of boiler . | 3′ 10″ | 4′ 5″ | 4′ 5″ | 4′ 9″ | 5′ 3″ | 5′ 4″ | 5′ 9″ | 6′ 2″ | 6′ 2″ |
| Length „ . | 9′ 0″ | 10′ 1″ | 13′ 2″ | 14′ 6″ | 14′ 9″ | 17′ 6″ | 19′ 4″ | 21′ 0″ | 26′ 3″ |
| Dia. of flue . | 24 | 28 | 29 | 31 | 34 | 34 | 36 | 39 | 39 |
| No. of Gallo-way tubes | — | — | — | — | 2 | 3 | 3 | 4 | 4 |
| Weight in cwts. | 44 | 67 | 77 | 104 | 110 | 139 | 153 | 180 | 215 |

TABLE 154.—**Cornish Boilers made by Messrs. Davey, Paxman & Co.**

| Nom. H.P. | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dia., boiler | 3′ 6″ | 3′ 8″ | 4′ 6″ | 4′ 6″ | 4′ 9″ | 4′ 9″ | 5′ 0″ | 5′ 6″ | 5′ 6″ | 5′ 9″ |
| Length „ | 9′ 0″ | 12′ 0″ | 12′ 0″ | 15′ 0″ | 15′ 0″ | 18′ 0″ | 20′ 0″ | 21′ 0″ | 24′ 0″ | 26′ 0″ |
| Dia. of flue, ins. | 24 | 24 | 30 | 30 | 32 | 32 | 33 | 36 | 38 | 38 |

**Seating for Cornish Boilers** (Figs. 1049—1051).

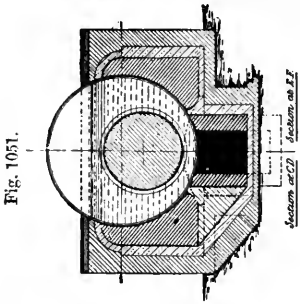



Fig. 1051.

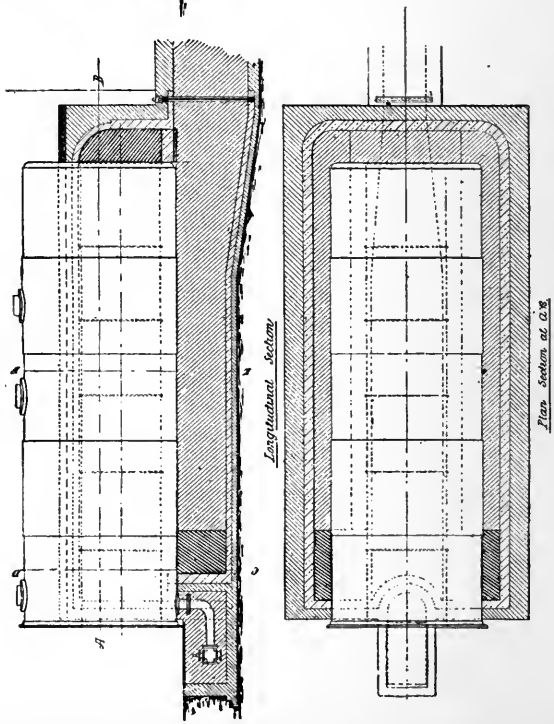



Fig. 1050.

Figs. 1049—1051.—Seating for Cornish Boilers.

The ordinary arrangement of flues for Cornish boilers is shown in the above figures, 1049, 1051 ; in all cases where possible, the flues should be made large enough to admit of thorough inspection being made.

TABLE 155.—**Cornish Boilers made by Messrs. Ruston, Proctor, Limited.**

| Nominal H.P. . | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 20 |
|---|---|---|---|---|---|---|---|---|---|
| Diam. of boiler. | 3′ 0″ | 3′ 6″ | 4′ 0″ | 4′ 6″ | 4′ 6″ | 5′ 0″ | 5′ 0″ | 5′ 6″ | 6′ 0″ |
| Length of boiler | 8′ 0″ | 9′ 0″ | 10′ 0″ | 12′ 0″ | 15′ 0″ | 16′ 0″ | 18′ 0″ | 19′ 0″ | 20′ 0″ |
| Diam. of flue . | 20 | 22 | 24 | 28 | 28 | 32 | 32 | 38 | 40 |
| No. Galloway cross tubes . | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 4 | 4 |

TABLE 156.—**Cornish Boilers made by Messrs. Ransomes, Sims & Jefferies, Limited.**

| Nom. H.P. | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| Dia., boiler | 3′ 6″ | 4′ 0″ | 4′ 6″ | 4′ 6″ | 5′ 0″ | 5′ 0″ | 5′ 6″ | 5′ 6″ | 6′ 0″ | 6′ 0″ |
| Length „ | 9′ 0″ | 10′ 0″ | 12′ 0″ | 15′ 0″ | 16′ 0″ | 19′ 0″ | 20′ 0″ | 23′ 0″ | 24′ 0″ | 27′ 0″ |
| Dia. of flue | 24 | 24 | 28 | 28 | 32 | 32 | 36 | 36 | 40 | 40 |
| No. Gallo. cross-tubes | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 6 |

**Double-Flued or Lancashire Boiler** (Figs. 1052, 1053).

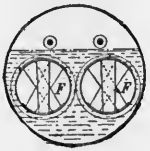



Fig. 1052.

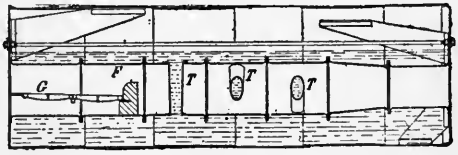



Fig. 1053.

This type is generally used for large boilers on land, and is very efficient and durable. Below are tables of dimensions of these boilers by the same English makers as those given of Cornish boilers, and in the same order.

TABLE 157.—**Dimensions of Lancashire Boilers.**

| Nominal H.P. . . . | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|
| Diameter of boiler . . | 6′ 2″ | 6′ 6″ | 6′ 8″ | 6′ 8″ | 7′ 0″ |
| Length . . . . . | 19′ 0″ | 22′ 0″ | 24′ 0″ | 27′ 0″ | 28′ 0″ |
| Diameter of flues . . | 28″ | 30″ | 30″ | 30″ | 32″ |
| Weight in cwts. . . . | 200 | 235 | 250 | 276 | 300 |

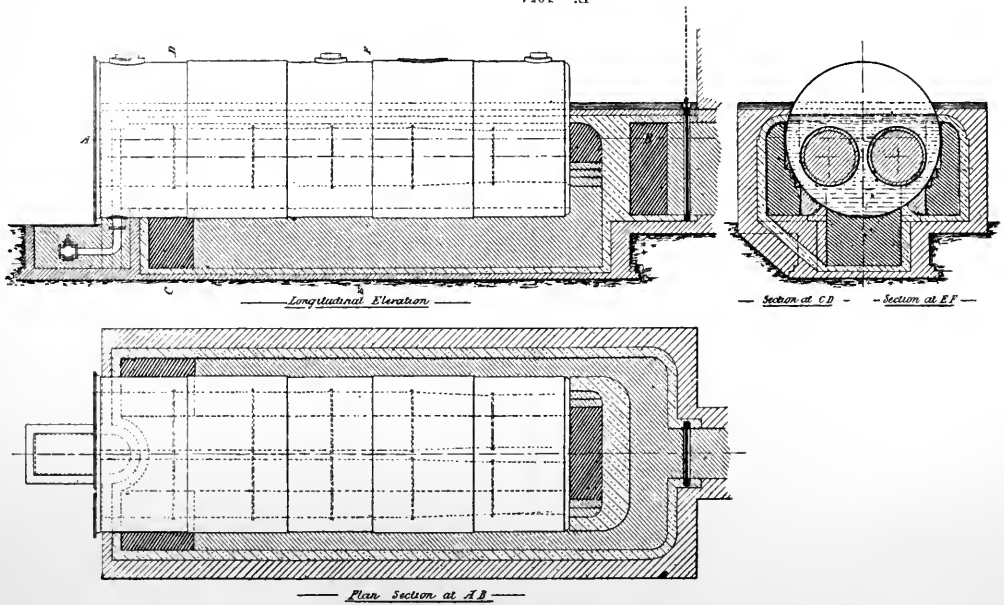



Fig. 1055.

Figs. 1054—1056.—Seating for Lancashire Boilers.

TABLE 158.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal H.P. | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| Diameter of boiler | 5′ 6″ | 5′ 6″ | 6′ 0″ | 6′ 3″ | 6′ 6″ | 6′ 9″ | 7′ 0″ | 7′ 6″ |
| Length of boiler | 19′ 0″ | 21′ 0″ | 22′ 6″ | 24′ 0″ | 26′ 0″ | 28′ 0″ | 30′ 0″ | 30′ 0″ |
| Diameter of flues | 24 | 24 | 27 | 28 | 30 | 31½ | 33 | 36 |

TABLE 159.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal H.P. | 18 | 22 | 25 | 28 | 30 | 35 | 40 | 50 |
| Diameter of boiler | 5′ 6″ | 6′ 0″ | 6′ 0″ | 6′ 6″ | 6′ 6″ | 6′ 6″ | 7′ 0″ | 7′ 0″ |
| Length of boiler | 19′ 0″ | 20′ 0″ | 24′ 0″ | 24′ 0″ | 26′ 0″ | 28′ 0″ | 28′ 0″ | 30′ 0″ |
| Diameter of flues | 22 | 26 | 26 | 29 | 29 | 29 | 31 | 31 |
| No. of Galloway cross-tubes | 6 | 6 | 6 | 6 | 6 | 8 | 8 | 10 |

TABLE 160.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Nominal H.P. | 16 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| Diameter of boiler | 6′ 0″ | 6′ 0″ | 6′ 6″ | 6′ 6″ | 7′ 0″ | 7′ 0″ | 7′ 6″ | 7′ 6″ |
| Length of boiler | 19′ 0″ | 22′ 0″ | 23′ 0″ | 26′ 0″ | 28′ 0″ | 30′ 0″ | 28′ 0″ | 30′ 0″ |
| Diameter of flues | 28 | 28 | 28 | 28 | 32 | 32 | 36 | 36 |
| No. of Galloway cross-tubes | 4 | 4 | 6 | 6 | 8 | 8 | 8 | 8 |

**Seating for Lancashire Boilers** (Figs. 1054—1056).

The flues in the above figs. (1054—1056), are shown arranged for the hot gases to pass through the flues, then down underneath the boiler, then round the sides, and finally to the chimney. With Cornish boilers the flues are usually arranged to take the hot gases round the sides first, and then along underneath the boiler. Each method has its advocates, but it is generally held that in Lancashire boilers the hottest possible gases should pass underneath, in order to act on the body of water between and below the flues; in Cornish boilers there is less water under the flue.

## Cornish Boilers of German Type, with Flue on one side.

Fig. 1057.

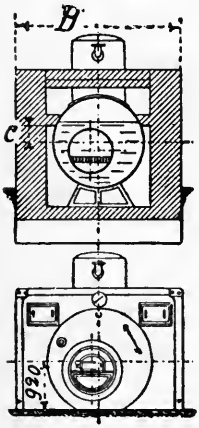



Fig. 1058.

Fig. 1059.

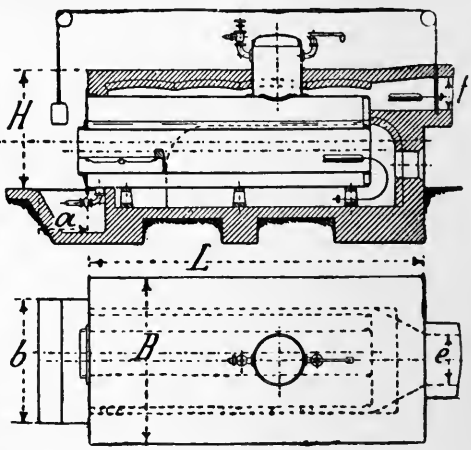


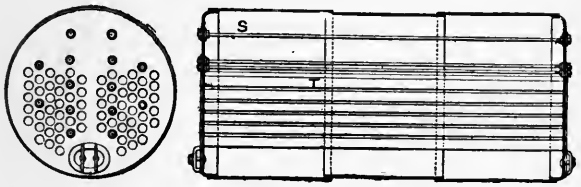

Fig. 1060.

TABLE 161.—**Dimensions of German Cornish Boiler Seating** (Figs. 1057—1060).

| Horse-power. | Heating-surface sq. feet. | L | B | H | *a* | *b* | *c* | *e* | *f* |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 54 | 95 | 77½ | 70 | 18 | 32 | 6 | 20 | 20 |
| 4 | 97 | 136 | 82 | 75 | 20 | 36 | 7 | 20 | 20 |
| 6 | 140 | 173 | 85 | 77 | 22 | 39 | 7¾ | 20 | 20 |
| 8 | 172 | 198 | 87 | 78 | 24 | 43 | 8 | 24 | 24 |
| 10 | 215 | 220 | 92 | 81 | 26 | 47 | 9 | 24 | 24 |
| 15 | 300 | 228 | 98 | 90 | 28 | 51 | 10 | 24 | 24 |
| 25 | 430 | 285 | 110 | 94 | 30 | 55 | 11 | 28 | 28 |
| 40 | 690 | 340 | 118 | 94 | 32 | 59 | 12 | 28 | 28 |
| 50 | 860 | 427 | 138 | 96 | 34 | 63 | 13½ | 28 | 28 |

All dimensions in Inches except heating-surface, which is given in square feet.

## Cylindrical Multitubular Boilers.




Figs. 1061, 1062.

TABLE 162.—**Dimensions of Multitubular Cylindrical Boiler** (Figs. 1061, 1062).

| Nominal H.P. . | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 25 | 30 | 35 | 40 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dia. of boiler . | 3½ | 3½ | 4 | 4 | 4½ | 4½ | 5 | 5 | 6 | 6 | 6½ | 6½ |
| Length „ | 6 | 7½ | 8 | 9 | 9½ | 10½ | 11½ | 12½ | 12½ | 13½ | 13½ | 1 |
| No. of tubes . | 22 | 22 | 28 | 28 | 32 | 32 | 38 | 44 | 40 | 52 | 60 | 60 |
| Dia. of tubes . | — | — | — | — | — | — | — | — | — | — | — | — |
| Heating-surface | — | — | — | — | — | — | — | — | — | — | — | — |

This type of boiler is set in brickwork, the furnace and flue doors being also built in.

The boiler is fired from below, and the gases pass along underneath the boiler and through the tubes, returning back by the sides to the chimney. The tubes are easily got at for cleaning, and almost any description of fuel may be used. These boilers are suitable for export, owing to their small size in proportion to their heating surface.

## Multitubular Loco-Type Boilers.

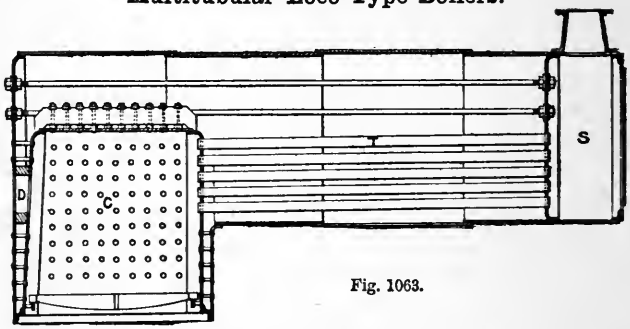



Fig. 1063.

TABLE 163.—**Multitubular Loco-Type Boilers for 140 lbs. working pressure.**

| Nominal Horse-power. | 8 | 10 | 12 | 16 | 20 | 25 | 30 | 40 |
|---|---|---|---|---|---|---|---|---|
| Diameter of boiler . | 31½ | 33½ | 35½ | 39 | 41½ | 47½ | 50 | 52 |
| Length of boiler . . | 135 | 146 | 148 | 162 | 172 | 187½ | 189½ | 235½ |
| Number of tubes . | 31 | 38 | 34 | 36 | 43 | 58 | 64 | 73 |
| Length of tubes . . | 77¼ | 81 | 81 | 96 | 102 | 108 | 108 | 123 |
| Diameter of tubes . | 2¼ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ |
| Heating surface . . | 144·2 | 158·3 | 189·7 | 230·2 | 285·5 | 398·0 | 439·5 | 618·4 |
| Length of fire-box . | 31 | 35 | 35 | 37 | 38 | 43½ | 45¾ | 56¾ |
| Grate area, sq. ft. . | 5 | 6·5 | 7·3 | 7·8 | 9·0 | 12·1 | 13·6 | 17·7 |
| Thickness of plates, tube . . . | ⅝ | ⅝ | ⅝ | ⅝ | ⅝ | ¾ | ¾ | ¾ |
| Thickness of fire-box, top and sides | 7/16 | 7/16 | 7/16 | ½ | ½ | ½ | ½ | ½ |
| Thickness of front plate, fire-box . | 7/16 | 7/16 | 7/16 | 7/16 | ½ | ½ | ½ | ½ |
| Thickness of front tube plate, fire-box | ⅝ | ⅝ | ⅝ | 11/16 | ¾ | ¾ | ¾ | ¾ |
| Thickness of barrel . | ⅜ | ⅜ | ⅜ | 7/16 | 7/16 | 7/16 | ½ | ½ |
| Diameter of chimney | 12 | 15 | 15 | 15 | 18 | 18 | 20 | 26 |
| Length of smoke-box | 24½ | 25 | 25 | 25 | 26½ | 31½ | 31½ | 40½ |

Dimensions in Inches, except heating surface which is in sq. feet.

This is a well-tried type of boiler, and is universally used for locomotives, and portable and traction engines.

## Multitubular Loco-Type Boilers.

These boilers are similar to those shown, fig. 1063, Table 163, but for smaller powers ; and are for 80 to 90 lbs. working pressure.

TABLE 164.—**Dimensions of Loco-Type Boilers.**

| Horse-power. | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|---|
| Dia. of boiler . | 28½ | 31½ | 33½ | 35½ | 37½ | 39 | 39 | 41½ | 43½ |
| Length „ . . | 102½ | 115 | 115½ | 117 | 125 | 129 | 133 | 139 | 146½ |
| No. of tubes . | 15 | 19 | 21 | 25 | 27 | 31 | 33 | 36 | 39 |
| Length „ . . | 57 | 66 | 67 | 67 | 72½ | 76 | 78 | 78¾ | 87¾ |
| Dia. „ . | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ |
| Total heating-surface of boiler | 66·9 | 94·5 | 105·5 | 122·0 | 140·7 | 165·5 | 179·5 | 197·8 | 234·3 |
| Length of fire-box | 22½ | 24½ | 25 | 25¼ | 26¼ | 27¼ | 29½ | 32¼ | 32¼ |
| Grate area, sq. ft. | 3·37 | 4·59 | 4·67 | 5·07 | 5·51 | 6·16 | 6·59 | 7·83 | 8·28 |
| Thickness of front tube | ½ | ½ | ½ | 9/16 | 9/16 | 9/16 | 9/16 | 9/16 | 5/8 |
| „ fire-box side & top plates | 5/16 | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 |
| Thickness of fire box front plate | 5/16 | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 |
| Thickness of fire box tube plate | ½ | ½ | ½ | 9/16 | 9/16 | 9/16 | 9/16 | 9/16 | 5/8 |
| Thickness of barrel plates | ¼ | ¼ | ¼ | 5/16 | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 |
| Dia. of chimney . | 8 | 9 | 10 | 12 | 12 | 12 | 12 | 15 | 15 |
| Length of smoke-box . | 17 | 19 | 19 | 19¾ | 20¾ | 20¾ | 20 | 20 | 21½ |

Dimensions in Inches, except heating surface which is given in sq. feet.

## Vertical Boilers.

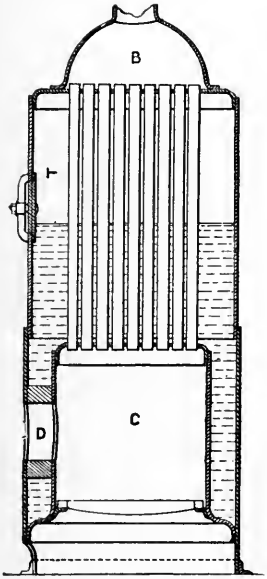



Fig. 1064.

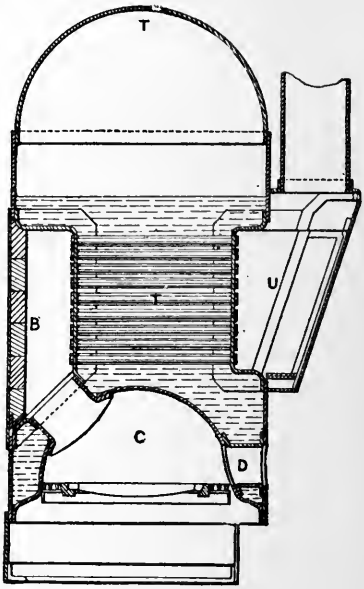



Fig. 1065.

Owing to the comparatively small space which vertical boilers occupy, and their convenient shape, they are largely used, notwithstanding the fact that their efficiency does not approach to either Cornish, Lancashire, or multitubular boilers. The form shown on fig. 1067, is in most general use, owing to its simplicity and cheapness ; it is at the same time perhaps the most wasteful of fuel, to do away with which defect many other forms of vertical boilers have been constructed, to give increased heating surface and greater economy. Fig. 1064 shows one of these arrangements, in which the uptake is dispensed with, the gases, &c., from the fire-box passing through vertical tubes to the chimney. Fig. 1065 shows a vertical boiler constructed by Messrs. Cochrane, of Birkenhead. In this

case the gases are conducted up one side of the boiler, and then pass through a number of horizontal tubes to the uptake ; the tubes being

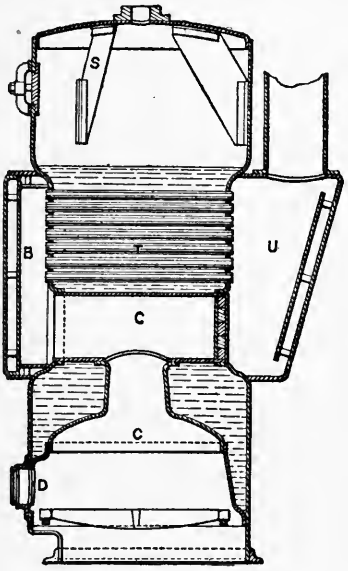



Fig. 1066.

arranged to give easy access for cleaning. Fig. 1066 shows a good form of vertical boiler by Messrs. Tinker, Shenton & Co.

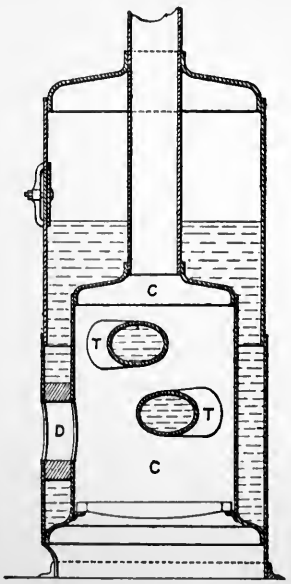



Fig. 1067.—Vertical Cross-Tube Boiler.

TABLE 165.—**Dimensions of Vertical Cross-Tube Boilers** (Fig. 1067).

| Nominal horse-power | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter of boiler | 30 | 33 | 36 | 39 | 39 | 42 | 48 | 48 | 51 | 57 |
| Height of boiler | 72 | 78 | 84 | 90 | 102 | 102 | 114 | 144 | 144 | 150 |
| Approx. heating surface in sq. ft. | 28½ | 38½ | 50 | 60 | 69 | 80 | 100 | 120 | 130 | 150 |
| Grate area, sq. ft. | 3½ | 4¼ | 5¼ | 6¼ | 6¼ | 7½ | 10¼ | 10¼ | 11½ | 15 |
| Number of cross-tubes | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| Shell plates, thickness | ¼ | ¼ | 5/16 | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | 3/8 |
| Fire-box, thickness | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 | 3/8 | 7/16 |
| Cross-tube, thickness | ¼ | ¼ | 5/16 | 5/16 | 5/16 | 5/16 | 5/16 | 5/16 | 5/16 | 5/16 |
| Uptake, thickness | ¼ | ¼ | ¼ | ¼ | ¼ | ¼ | 3/8 | 3/8 | 3/8 | 3/8 |
| Crown, thickness | 5/16 | 5/16 | 5/16 | 3/8 | 3/8 | 3/8 | ½ | ½ | ½ | ½ |
| Diameter of cross-tubes | 7 | 8 | 8 | 8 | 8 | 9 | 9 | 9 | 9 | 10 |
| Height to top of fire-box | 41 | 44 | 48 | 51 | 57 | 57 | 64 | 81 | 81 | 84 |
| Diameter of fire-box | 26 | — | — | — | — | — | — | — | — | — |

Dimensions in Inches, except heating surface.

These vertical boilers are extensively used on board ship as donkey boilers, and also for working steam cranes.

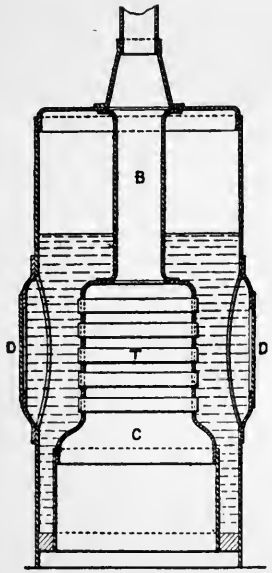



Fig. 1068.

TABLE 166.—**Dimensions of Hopwood's Vertical Boilers** (Fig. 1068).

| Nominal horse-power | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|---|---|
| Diameter of boiler | 27½ | 33 | 36 | 38½ | 41 | 43 | 48¾ | 52 |
| Height of boiler | 66 | 77 | 81 | 90 | 91 | 96 | 111 | 117 |
| Height to uptake (B) | 41¾ | 47½ | 52 | 54¾ | 60 | 64 | 76 | 79 |
| No. of tubes | 12 | 20 | 28 | 24 | 28 | 26 | 36 | 36 |
| Diameter of tubes | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ | 2½ |
| Length of tubes | 16 | 20¾ | 20¾ | 26½ | 27 | 28¼ | 34½ | 34½ |
| Heating-surface (total) sq. feet | 25 | 47·7 | 55·1 | 64·6 | 75·8 | 90·1 | 121·2 | 141·8 |
| Grate area | 2·94 | 4·31 | 5·24 | 5·62 | 6 89 | 7·56 | 9·05 | 11·7 |

These boilers have manholes at D for access to tubes. The tubes are higher at one end than at the other. Vertical stays are used in the larger sizes, placed round the uptake, and connecting top of fire-box to crown of boiler.

Small vertical boilers are used for steam fire-engines where steam has to be raised in the very shortest possible time. They have a

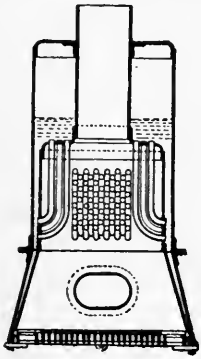


Fig. 1069.—Fire-engine boiler with cross and vertical tubes.

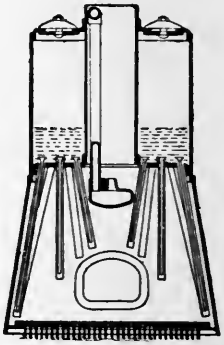


Fig. 1070.—Fire-engine boiler with Field tubes.

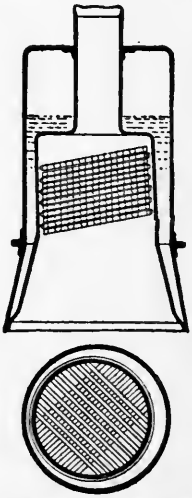


Fig. 1071.—Fire-engine boiler with cross-tubes.

very small water capacity, and are made to take to pieces for cleaning. Figs. 1069 to 1071, show in diagram types of these boilers.

## Marine Boilers.

The type of marine boiler has gradually settled down, after many modifications, into an internally fired flue and tube boiler, and has

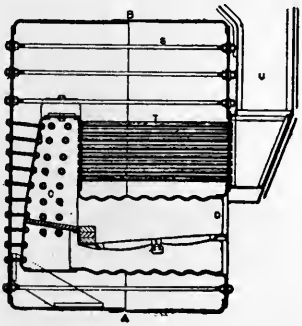


Fig. 1072.

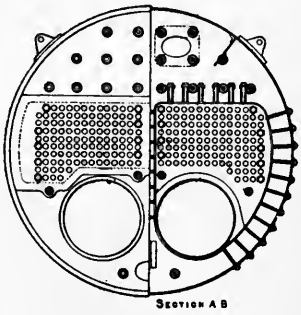



Fig. 1073.

now been successfully used on board ship for pressures up to 170 lbs.; 160 being, however, the usual limit. Figs. 1072, 1073, show in diagram the general construction of the modern marine boiler.

In torpedo boats the locomotive type of boiler, as well as the above, was largely used, but now they are entirely replaced by water-tube boilers.

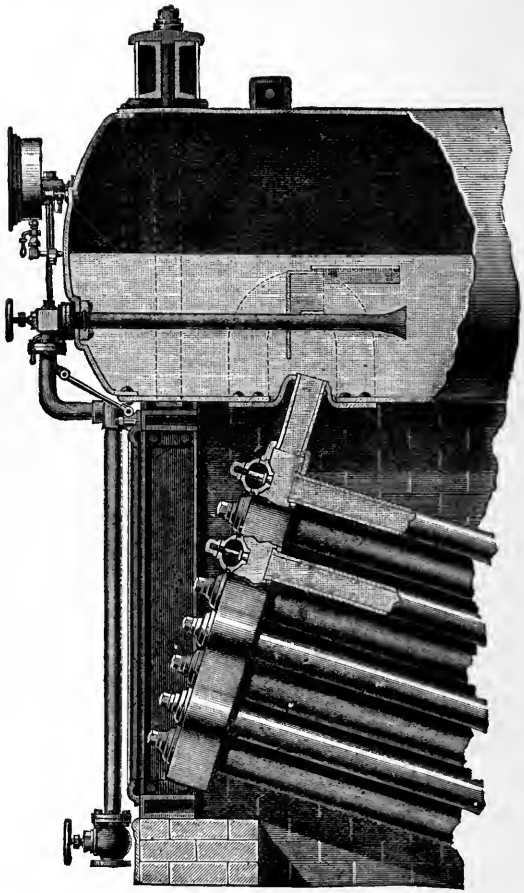


Fig. 1074.

Fig. 1075.

## Water-Tube Boilers.

A very great advance has been made in the construction of this most important type of boiler in the last few years, and now numbers of them are in use both on land and sea. For land use, a feature important in towns liable to sudden fogs is that steam can be very

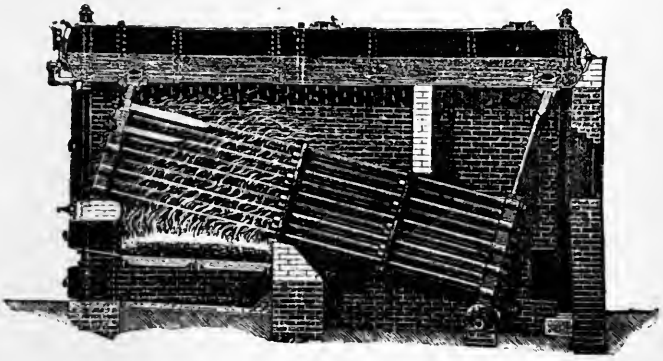


Fig. 1076.

quickly raised. This is of special advantage in electric light stations, where a sudden fog or darkness causes an immediate demand for more boiler power and quick steam raising is imperative. Another advantage is that the boilers can be taken apart and carried into works where it would be impossible to pass a large boiler in whole. At sea their lightness is perhaps one of the most important points in their favour. Fig. 1076 shews the well-known type of Messrs. Babcock and Willcox. The tubes are expanded into connecting boxes in zigzag, figs. 1074, 1075.

Fig. 1076 shews the arrangement of flues, and fig. 1074 a partial longitudinal section taken at the front end of the boiler. A mud drum is provided, to form a receptacle for the deposit as it falls down into the more quiescent parts of the boiler. Messrs. Babcock's boiler is largely used in electric light stations, with working pressures of 120 to 180 lbs. per square inch. The steam separates from the water in the large receiver forming the upper part of the boiler.

The Belleville water-tube boiler was invented by M. Belleville as long ago as 1849, but has only of late years been brought to perfection. In the French navy it has been adopted for many years, and is now received with favour in this country, and is being supplied to some of the newest cruisers, also to several mail steamers.

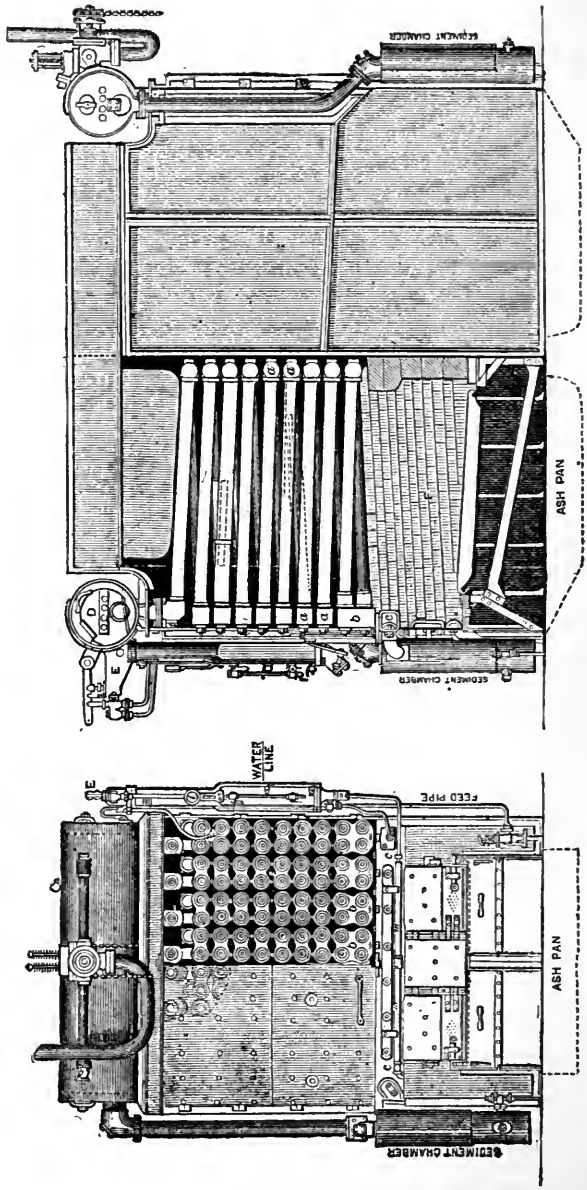



Fig. 1077.—Belleville Boiler. Marine Type.

The general construction of these boilers is that of a number of flattened spirals, formed by screwing the ends of straight tubes into junction caps of malleable cast-iron or steel. These caps are placed vertically above one another, the upper end of one tube being on the same level as the lower end of the one above it.

The tubes are slightly inclined to the horizontal, and the lower cap of each flattened spiral or element is connected to a horizontal cross tube at the front of the boiler, called the feed collector.

The upper tube is connected to the lower part of a cylindrical steam receiver placed outside the boiler casing. A vertical circulating pipe, also placed outside the casing, conveys the down current to a mud drum, placed at the base of the boiler, the upper part of which is connected to the feed collector.

The feed water is delivered into the steam receiver at the end remote from the inlet of the down pipe, passes along the receiver bottom down the external pipe, through the mud drum into the feed collector, and thus into the several elements, to be treated by the action of the fire on its way upwards through the tubes, from which it emerges into the receiver a mixture of water and steam. The latter is separated by baffle and dash plates from the former, which passes along its course with fresh feed-water. The admission of the feed-water is regulated by a self-acting arrangement. The position of the water level is at the fourth row of tubes from the top.

Fig. 1077 gives two views of the marine type of Belleville boiler. In both figures a part of the casing is removed to shew the arrangement of the tubes.

It is an essential feature in M. Belleville's system that the boiler pressure should be considerably higher than the working pressure of the engines. A reducing valve is therefore introduced between the boiler and engine. The effect of thus wire-drawing the steam slightly superheats it and delivers it dry to the engine. The tubes in these boilers are from 3 to 5 inches diameter. At the front end doors are provided which can be readily removed and replaced when steam is down for cleaning out the tubes. As the tubes are comparatively short for their diameter the cleaning out can be done with ease.

Steam can be got up quickly, in from 10 minutes in the smallest to one hour in large steamers.

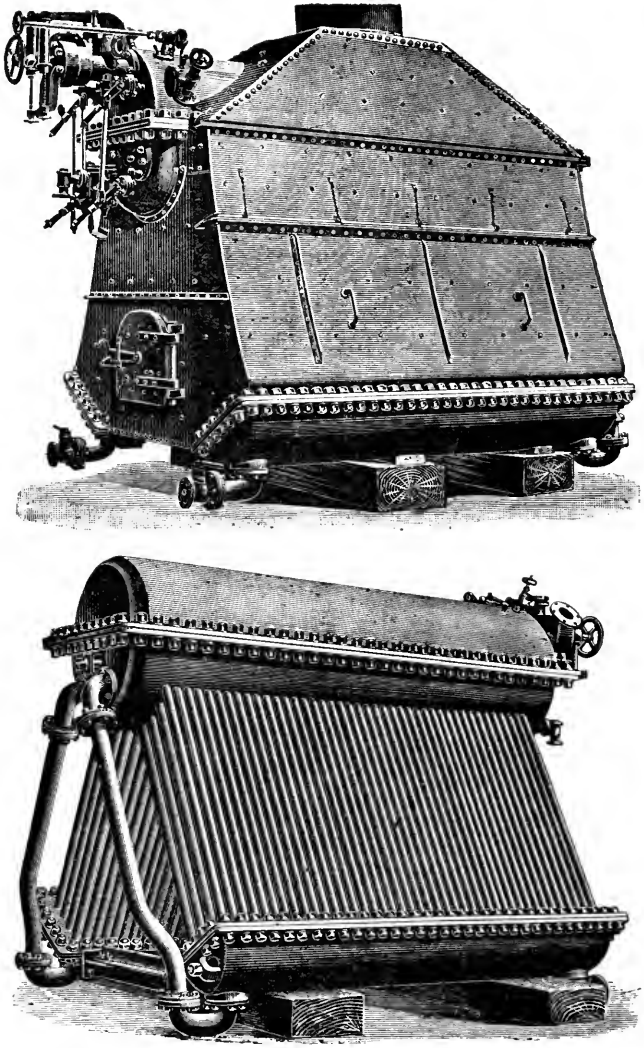
Compared with cylindrical marine boilers the head room required is small, 12 feet 6 inches for the largest size, and they are considerably lighter in weight than most other boilers. Taking an example, a range of twelve cylindrical boilers, with a grate area of 494 square

TABLE 167.—**Particulars of Belleville Boilers made by Messrs. Maudslay, Sons & Field, Ltd. Stationary Type. Working Pressure, 170 lbs. per square inch.**

| MARK. | Area of | | Diameter of Tubes in Inches. | Space Required. | | | Pounds of Dry Steam guaranteed per Hour. |
|---|---|---|---|---|---|---|---|
| | Heating Surface, in sq. ft | Fire Grate, in sq ft. | | Depth. | Width. | Height. | |
| A. No. 3 | 290 | 9 | 3¼ | 6′ 9¼″ | 4′ 11″ | 10 6′ | 1,000 |
| A. No. 4 | 380 | 12 | do. | do. | 5′ 7″ | do. | 1,350 |
| A. No. 5 | 470 | 15 | do. | do. | 6′ 4″ | do. | 1,700 |
| A. No. 6 | 560 | 18 | do. | do. | 7′ 0″ | do. | 2,050 |
| A. No. 7 | 650 | 21 | do. | do. | 7′ 9″ | do. | 2,400 |
| A. No. 8 | 740 | 24 | do. | do. | 8′ 5″ | do. | 2,750 |
| A. No. 9 | 830 | 27 | do. | do. | 9′ 2″ | do. | 3,100 |
| A. No. 10 | 920 | 30 | do. | do. | 9′ 10″ | do. | 3,450 |
| A. No. 11 | 1,010 | 33 | do. | do. | 10′ 7″ | do. | 3,800 |
| A. No. 12 | 1,100 | 36 | do. | do. | 11′ 4″ | do. | 4,150 |
| B. No. 4 | 520 | 17·00 | 4 | 7′ 11¼″ | 6′ 10″ | 12′ 3″ | 2,000 |
| B. No. 5 | 640 | 21·25 | do. | do. | 7′ 9″ | do. | 2,500 |
| B No. 6 | 760 | 25·50 | do. | do. | 8′ 7″ | do. | 3,000 |
| B. No. 7 | 880 | 29·75 | do. | do. | 9′ 5″ | do. | 3,500 |
| B. No. 8 | 1,000 | 34·00 | do. | do. | 10′ 3″ | do. | 4.000 |
| B. No. 9 | 1,120 | 38·25 | do. | do. | 11′ 2″ | do. | 4,500 |
| B. No. 10 | 1,240 | 42·50 | do. | do. | 12′ 2″ | do. | 5,000 |
| C. No 4 | 790 | 26 | 5 | 9′ 44¼″ | 9′ 3′ | 13′ 9″ | 3,200 |
| C. No. 5 | 989 | 32 | do. | do. | 9′ 6′ | do. | 3,950 |
| C. No. 6 | 1,170 | 39 | do. | do. | 10′ 6″ | do. | 4,700 |
| C. No. 7 | 1,360 | 46 | do. | do. | 11′ 7″ | do. | 5,450 |
| C. No. 8 | 1,550 | 53 | do. | do. | 12′ 7″ | do. | 6,200 |
| C. No. 9 | 1,740 | 60 | do. | do. | 13′ 8″ | do. | 6,950 |
| C. No. 10 | 1,930 | 67 | do. | do. | 14′ 9″ | do. | 7,700 |

TABLE 168.—**Particulars of Belleville Boilers made by Messrs. Maudslay, Sons & Field, Ltd. Portable Type. Working Pressure, 170 lbs. per square inch.**

| MARK | Area of. | | Diameter of Tubes in Inches. | Space Required. | | | Pounds of Dry Steam guaranteed per Hour. |
|---|---|---|---|---|---|---|---|
| | Heating Surface, in sq. ft. | Fire Grate, in sq. ft. | | Depth. | Width. | Height. | |
| T. A. No. 4 ..... | 50 | 1·6 | 3¼ | 2′ 7″ | 2′ 10″ | 7′ 5″ | 220 |
| T. A. No. 5 ..... | 70 | 2·5 | do. | 2′ 11″ | 3′ 2″ | do. | 330 |
| T. A. No. 6 ..... | 95 | 3·7 | do. | 3′ 3″ | 3′ 6″ | do. | 490 |
| T. A. No. 7 ..... | 120 | 5·1 | do. | 3′ 7″ | 3′ 10″ | do. | 660 |
| T. A. No. 8 ..... | 150 | 6·8 | do. | 3′ 11″ | 4′ 2″ | do. | 820 |
| T. B. No. 5 ..... | 120 | 4·4 | 4 | 3′ 7″ | 3′ 6″ | 8′ 1″ | 550 |
| T. B. No. 6 ..... | 160 | 6·1 | do. | 3′ 11″ | 3′ 11″ | do. | 710 |
| T. B. No. 7 ..... | 200 | 8·0 | do. | 4′ 3″ | 4′ 4″ | do. | 930 |
| T. B. No. 8 ..... | 250 | 10·3 | do. | 4′ 7″ | 4′ 8″ | do. | 1,200 |
| T. B. No. 9 ..... | 300 | 12·9 | do. | 4′ 11″ | 5′ 1″ | do. | 1,450 |
| T. B. No. 10 ..... | 360 | 15·6 | do. | 5′ 3″ | 5′ 6″ | do. | 1,750 |



Figs. 1078, 1079.—Water Tube Boiler by Messrs. Yarrow & Co.

feet and 14,480 square feet of heating surface weighs, including water and all fittings, 440 tons; the Belleville boilers supplying the place of the above grate area 674 square feet, heating surface 21,100 square feet, weight, including water and all fittings, 249·5 tons. The boilers are made of different types suitable for stationary, portable or marine work. The stationary type is set in brick work, the portable type is built light and is used with portable engines, fire engines, steam cranes, &c., an auxiliary type specially strong for supplying steam to winches and for use with salt water.

Messrs. Yarrow, of Poplar, have brought out a simple and highly efficient water-tube boiler, the general features of which are shown in figs. 1078, 1079. In this type of boiler all the tubes are straight, and the upper ends are secured into the steam drum, which is made in halves and bolted together to facilitate cleaning and repairs, and the lower ends are secured into semicircular vessels, of which the top flat plates into which the tubes enter are bolted to the semicircular base.

The two groups of tubes are arranged in an inclined direction, one on each side of the furnace. In order to study the circulation in water-tube boilers, Messrs. Yarrow carried out a series of experiments, and arrived at the conclusion that the circulation in the tubes nearest the fire was established at once, and that any additional heating of the tubes clearly increased the circulation, so that no external pipes, called "down-comers," were necessary—the outer tubes, those furthest from the fire, acting as down-comers themselves.

These boilers are being used on the fastest type of vessels afloat, the Torpedo Boat Destroyers, and Messrs. Yarrow have built a number of them for Dutch cruisers. The boilers for these cruisers have steel tubes $1\frac{5}{8}''$ diameter and 5′.0″ long, arranged in ten rows on each side of the furnace; the area of grate surface is 40·25 square feet, the heating surface 2,017 square feet, their weight is about 0·24 cwt. per indicated horsepower, whilst that of return-tube marine boilers is about 1·07 cwt. per indicated horsepower. A water-tube boiler of this type, capable of supplying steam to an engine indicating 3,000 HP., occupies about the same space as an ordinary return-tube marine boiler supplying steam to an engine indicating 2,250 HP.

The water-tube boiler by Messrs. Thornycroft, of Chiswick, differs in many respects from that of Messrs. Yarrow in construction, but in efficiency but little difference seems to exist. From figs. 1080, 1081, it will be seen that the tubes are curved, and are inserted into the upper or steam-drum above the water line; and in the special type (fig. 1081) there is one lower drum and one upper one, the furnace being divided and placed outside the group of tubes. In another

Fig. 1080.



Fig. 1081.

Water Tube Boiler by Messrs. Thornycroft & Co.

type of boiler by the same firm, there are two lower drums, and the furnace is arranged between the two groups of tubes. The former is named the "Daring" type and the latter the "Speedy" type, after the torpedo boats to which they have been applied. The bends in the tubes are said to give more heating surface, and to give an amount of elasticity, to prevent undue strain by difference of temperature. In the "Speedy" there were eight Thornycroft boilers, supplying steam to engines indicating about 4,500 HP.; the area of the grate in each boiler was 25·5 square feet, the heating surface 1,840 square feet, the weight of each boiler empty about 8·94 tons.

Many other water-tube boilers are at present in use, and new varieties are still being brought out. Amongst those which are coming into use are the "Normand" boiler of the Thornycroft type; the "Clyde" boiler by Fleming and Ferguson; the "Stirling" boiler; the "Niclausse" boiler: in this boiler the tubes are placed as in the Babcock boiler, that is, nearly horizontal, but they are connected by headers at the front end only, thus all the joints are readily accessible. The header is divided vertically into two parts by a division plate, the tubes are also double; the outer tube is fixed into the back plate of the header, and the closed end rests on support at the back of the furnace; the inner tube is fixed in the division plate of the header and is open at both ends, the open back end being a few inches short of the closed end of the outer tube; by this means circulation is kept up briskly when the boiler is under steam. The headers are connected to a drum over the front part of the boiler. It is very probable that this boiler will be more generally used as it becomes more known. Other varieties of water-tube boilers are too numerous to mention, but most of them are designs based on those mentioned above.*

* See "Bertin's Marine Boilers," translated by L. S. Robertson. London: John Murray.

## Lever Safety Valve.

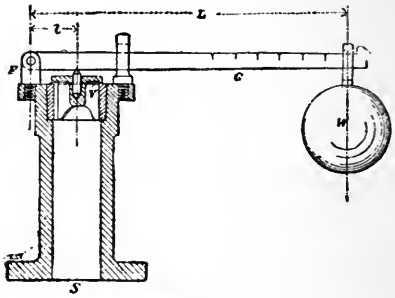



Fig. 1082.

Lever safety valves of the type shewn in Fig. 1082 are largely used but are rather giving way to the more reliable type of Dead-Weight Safety Valves, fig. 1084.

The weight for any point of blow-off pressure may be calculated by the formula below. In all but very small valves the weight of the valve itself and of the lever must be taken into account :—

A = area of valve in square inches.
L = length of lever in inches from fulcrum to centre of weight W.
$l$ = length of the short arm of the lever in inches from centre of valve to fulcrum.
$w$ = weight of lever.
G = distance of centre of gravity of lever from fulcrum in inches.
V = weight of valve in lbs.
W = „ in lbs. to balance blow-off pressure.
P = blow-off pressure in lbs. per square inch.

$P = \frac{W L}{A l}$ = blow-off pressure in lbs. per square inch due to weight W.

$W = \frac{A P l}{L}$ = Weight for given blow-off pressure P, without accounting for weights of valve and lever.

$\frac{G w}{l A}$ = Pressure in lbs. per square inch due to weight of lever.

$\frac{V}{A}$ = Pressure in lbs. per square inch due to weight of valve.

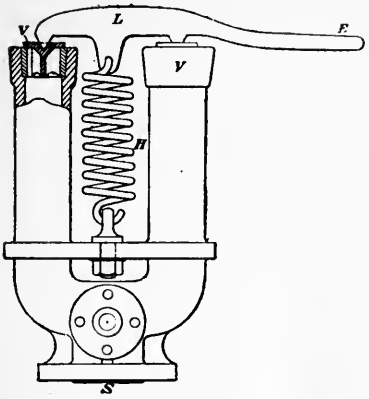



Fig. 1083.

TABLE 169.—**Dimensions of Ramsbottom's Safety Valves** (Fig. 1083).

| | | | | | | |
|---|---|---|---|---|---|---|
| Diameter of valves . . . | $1\frac{1}{2}$ | $1\frac{3}{4}$ | $2\frac{1}{8}$ | $2\frac{1}{2}$ | 3 | $3\frac{1}{2}$ |
| Diameter of flange . . | $7\frac{1}{4}$ | 9 | 9 | 10 | $11\frac{1}{2}$ | 12 |
| Between centres of valves V | $6\frac{1}{2}$ | 7 | $7\frac{1}{2}$ | $8\frac{1}{2}$ | $9\frac{1}{2}$ | $9\frac{3}{4}$ |
| Height from flange to top of casting . . . | 16 | $17\frac{1}{2}$ | $18\frac{3}{4}$ | $21\frac{1}{2}$ | $23\frac{1}{4}$ | $25\frac{1}{2}$ |
| Thickness of lever . . | $\frac{9}{16}-\frac{5}{16}$ | $\frac{5}{8}-\frac{3}{8}$ | $\frac{3}{4}-\frac{7}{16}$ | $\frac{7}{8}-\frac{1}{2}$ | $\frac{7}{8}-\frac{1}{2}$ | $\frac{7}{8}-\frac{1}{2}$ |
| Total length of lever . . | $16\frac{1}{4}$ | $17\frac{3}{4}$ | $18\frac{1}{2}$ | 26 | $26\frac{3}{8}$ | $26\frac{3}{4}$ |
| Length of spring . . . | $6\frac{1}{8}$ | $6\frac{7}{8}$ | $6\frac{11}{16}$ | $8\frac{3}{8}$ | $9\frac{5}{16}$ | $10\frac{7}{16}$ |
| Diameter of spring . . . | $2\frac{1}{2}$ | $2\frac{3}{4}$ | 3 | $3\frac{1}{2}$ | $3\frac{1}{2}$ | $3\frac{3}{4}$ |
| Pull on spring for 140 lbs. pres. | 494·7 | 473·4 | 992·8 | 1374·2 | 1979·0 | 2693·8 |
| Pull on spring for 90 lbs. pres. | 318·0 | 432·9 | 638·2 | 883·4 | 1272·2 | 1731·7 |

Dimensions are given in Inches.

A loose link (not shown in the figure) is provided, to connect the lever L with the eye to which the spring is attached, so that, if the spring should break, the lever would be held by the link, and thus the valve would only blow off, but not leave the seat.

### Dead-Weight Safety Valve.

Fig. 1084 represents a group of 3 dead-weight safety valves, one of the group being shown in section. This class of valve is made single, or with several valves in a group attached to the same base. The valve V is fixed in the interior of the circular casting C, on

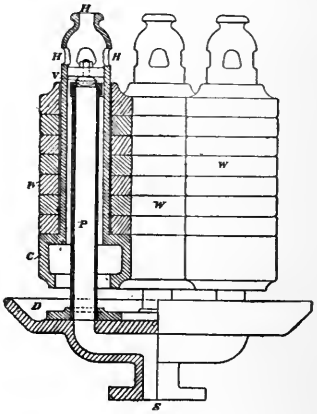



Fig. 1084.

which are placed the weights *w*, *w*. The seating for the valve is fixed on the top of the pipe P. The pipe in fig. 1084 is shown of wrought iron, although often made of cast iron. This type of safety valve requires no guides, as all the weights are below the valve, and therefore it returns by its own gravity to its proper place.

It is also very difficult to tamper with, owing to the large increase of weight required to make any appreciable difference to the blowing off pressure.

TABLE 170.—**Hyperbolic Logarithms.**

| No. | Hyp. log. | No. | Hyp. log. | No. | Hyp. log. | No. | Hyp. log. |
|---|---|---|---|---|---|---|---|
| 1 | 0·00000 | 26 | 3·25810 | 51 | 3·93183 | 76 | 4·33073 |
| 2 | 0·69315 | 27 | 3·29584 | 52 | 3·95124 | 77 | 4·34381 |
| 3 | 1·09861 | 28 | 3·33220 | 53 | 3·97029 | 78 | 4·35671 |
| 4 | 1·38629 | 29 | 3·36730 | 54 | 3·98898 | 79 | 4·36945 |
| 5 | 1·60944 | 30 | 3·40120 | 55 | 4·00733 | 80 | 4·38203 |
| 6 | 1·79176 | 31 | 3·43399 | 56 | 4·02535 | 81 | 4·39445 |
| 7 | 1·94591 | 32 | 3·46574 | 57 | 4·04305 | 82 | 4·40672 |
| 8 | 2·07944 | 33 | 3·49651 | 58 | 4·06044 | 83 | 4·41884 |
| 9 | 2·19722 | 34 | 3·52636 | 59 | 4·07754 | 84 | 4·43082 |
| 10 | 2·30259 | 35 | 3·55535 | 60 | 4·09434 | 85 | 4·44265 |
| 11 | 2·39790 | 36 | 3·58352 | 61 | 4·11087 | 86 | 4·45435 |
| 12 | 2·48491 | 37 | 3·61092 | 62 | 4·12713 | 87 | 4·46591 |
| 13 | 2·56495 | 38 | 3·63759 | 63 | 4·14313 | 88 | 4·47734 |
| 14 | 2·63906 | 39 | 3·66356 | 64 | 4·15888 | 89 | 4·48864 |
| 15 | 2·70805 | 40 | 3·68888 | 65 | 4·17439 | 90 | 4·49981 |
| 16 | 2·77259 | 41 | 3·71357 | 66 | 4·18965 | 91 | 4·51086 |
| 17 | 2·83321 | 42 | 3·73767 | 67 | 4·20469 | 92 | 4·52179 |
| 18 | 2·89037 | 43 | 3·76120 | 68 | 4·21951 | 93 | 4·53260 |
| 19 | 2·94444 | 44 | 3·78419 | 69 | 4·23411 | 94 | 4·54329 |
| 20 | 2·99573 | 45 | 3·80666 | 70 | 4·24850 | 95 | 4·55388 |
| 21 | 3·04452 | 46 | 3·82864 | 71 | 4·26268 | 96 | 4·56435 |
| 22 | 3·09104 | 47 | 3·85015 | 72 | 4·27667 | 97 | 4·57471 |
| 23 | 3·13549 | 48 | 3·87120 | 73 | 4·29046 | 98 | 4·58497 |
| 24 | 3·17805 | 49 | 3·89182 | 74 | 4·30407 | 99 | 4·59512 |
| 25 | 3·21888 | 50 | 3·91202 | 75 | 4·31749 | 100 | 4·60517 |

Hyp. log. 10, correct to eight places of decimals, = 2·30258509.

Common logs. multiplied by 2·30258 give hyperbolic logs.

Hyp. log. 75 = 4·31749.

Hyp. log. 7·5 = 4·31749 − hyp. log. 10.

·31749 − 2·30258 = 2·01491 the hyp. log. of 7·5.

TABLE 171.—**Temperatures, Volumes, and Pressures of a Pound of Steam.**

| Temperatures. | | Absolute Pressures in lbs. per square inch. | Volume occupied by a pound of Steam in cubic feet. |
|---|---|---|---|
| Fahr. | Centi. | | |
| 32 | 0 | 0·085 | 3390 |
| 68 | 20 | 0·333 | 934·6 |
| 95 | 35 | 0·806 | 404·8 |
| 122 | 50 | 1·78 | 192·0 |
| 149 | 65 | 3·62 | 98·45 |
| 176 | 80 | 6·86 | 53·92 |
| 203 | 95 | 12·26 | 31·26 |
| 212 | 100 | 14·70 | 26·36 |
| 230 | 110 | 20·80 | 19·03 |
| 275 | 135 | 45·49 | 9·124 |
| 302 | 150 | 69·21 | 6·153 |
| 329 | 165 | 101·9 | 4·280 |
| 356 | 180 | 145·8 | 3·057 |
| 365 | 185 | 163·3 | 2·748 |
| 383 | 195 | 203·3 | 2·236 |

**Formulæ for Steam Pressure and Volume Curves.**

V = volume in cubic feet to the pound.
P = pressure in lbs. per square inch.

$$V = 26{\cdot}36 \left(\frac{14{\cdot}7}{P}\right)^{\frac{n}{m}}$$

$$P = 14{\cdot}7 \left(\frac{26{\cdot}36}{V}\right)^{\frac{m}{n}}$$

$\frac{m}{n} = \frac{17}{16}$ for Rankine's curve,

$\frac{m}{n} = \frac{10}{9}$ for the so-called $\frac{10}{9}$ curve,

$\frac{m}{n} = \frac{14}{10}$ for the approximate adiabatic curve.

## Feed Pumps.

Considerable attention has of late years been given to the design of feed pumps. In early steam engines the feed pump was practically a part of the engine, but with the necessity of using large installations of engines and boilers it became necessary to separate the feed pump from the engine and place it near to the boilers.

A large number of feed pumps have been made with steam cylinders working the pump through the medium of crank shaft and connecting rods; of late years the demand has been for direct-acting pumps working without the intervention of connecting rods or cranks.

A great many varieties of direct-acting pumps are in use, and one very successful one may be taken as a type of the best practice in feed pumps.

Messrs. Weir's feed pump is one that forces the water into the boiler slowly and steadily, and is much in favour at sea and on land. Fig. 1085 shows a section through the feed pump; the steam is admitted to the main valve by means of a small auxiliary valve at the back, and the admission is so managed that the steam valve is always in a position ready to start the pump when steam is turned on. The arrangement of the steam and pump valves is clearly shown in the figure.

The valve gear consists of a main and auxiliary valve. The main valve is for distributing steam to the cylinders; the auxiliary for distributing steam to work the main valve. The main valve moves horizontally from side to side, being driven by steam admitted and exhausted from each end alternately. The auxiliary valve is actuated by lever gear from the rod of the pump, and moves on a face on the back of the main valve, and in a direction at right angles to the main valve. By this arrangement there is no dead centre, the action being absolutely positive, because the only possible position in which the main valve can rest is at full travel—either for an up or down stroke of the piston.

Both the main and auxiliary valves are simply slide valves, but the former is half round, the round side working on the cylinder port face, which is bored out on one side to fit the valve. On the back of this main valve a flat face is formed for the auxiliary valve to work upon. Both ends of the main valve are lengthened so as to project beyond the port face, and are turned cylindrical with flat ends. Caps are fitted on each of these ends forming cylinders, which

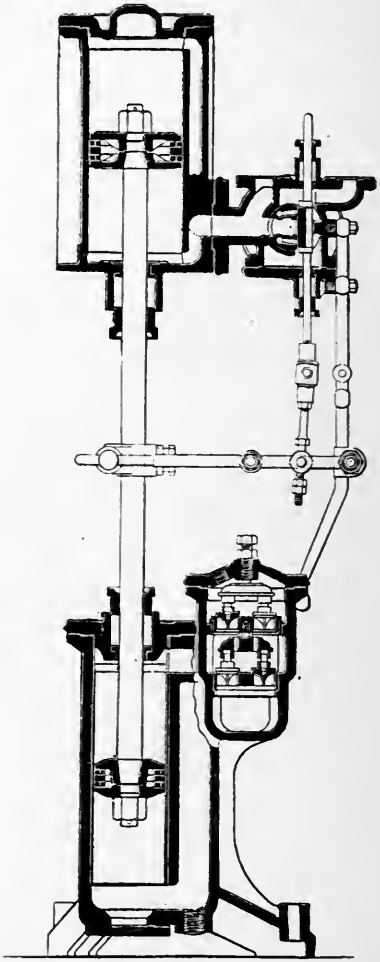


Fig. 1085.

are closed at the mouths by the flat ends of the main valve, which act as pistons.

The function of the auxiliary valve is to admit steam through the ports on the back of the main valve to move the main valve from side to side. The ports for admitting steam to the top and bottom of the cylinder are arranged to cut off before the end of the stroke, and so slow down the pump, thus permitting the water valves to settle quietly and relieve the connections from any shock. On the last quarter of the stroke the steam is thus used expansively, so effecting a considerable economy in steam consumption. Provision is made, however, by turning round the caps covering the end of the main valve for admitting live steam during the entire stroke, as, when the pumps are starting and the metal is cold, the steam condenses and it is necessary to clear out the chambers of water. These caps are turned by means of the gunmetal spindles with indicating pointers at each side of the steam valve chest. When the pump is fairly started, these bye-passes—one for the up-stroke and one for the down—are closed till the pump is working silently. The main and auxiliary valves are practically the only two moving parts in the valve chest. The stroke can be adjusted while the pump is working by the nuts on the valve spindle in accordance with the centre punch marks on the front stay, and is constant.

These pumps are sometimes arranged in pairs to work compound side by side. Table 172 gives sizes and capacities of the standard pumps made for land installations.

TABLE 172.—**Standard List of Sizes and Dimensions of the Weir Direct-Acting Pump for Land Installations.**

| Diameter of pump. | Cylinder of pump. | Length of stroke. | Gallons discharged per double stroke. | *Gallons discharged per hour at 12 double strokes per minute. | Floor space. | Height. |
|---|---|---|---|---|---|---|
| 5½″ | 7½″ | 15″ | 2·49 | 1792·8 | 1′ 5½″ × 1′ 7″ | 6′ 4½″ |
| 6″ | 8″ | 15″ | 2·94 | 2206·8 | 1′ 9½″ × 1′ 10″ | 6′ 10″ |
| 6″ | 8″ | 18″ | 3·53 | 2541·6 | 1′ 9½″ × 1′ 10″ | 7′ 7″ |
| 7″ | 9½″ | 18″ | 4·86 | 3499·2 | 1′ 10″ × 2′ 0″ | 7′ 7″ |
| 7″ | 9½″ | 21″ | 5·67 | 4082·4 | 1′ 10″ × 2′ 0″ | 8′ 4″ |
| 8″ | 10½″ | 18″ | 6·352 | 4573·4 | 2′ 2″ × 2′ 3″ | 8′ 0″ |
| 8″ | 10½″ | 21″ | 7·43 | 5349·6 | 2′ 2″ × 2′ 3″ | 8′ 9″ |
| 8″ | 10½″ | 24″ | 8·49 | 6113·8 | 2′ 2″ × 2′ 3″ | 9′ 6″ |
| 9″ | 12″ | 21″ | 9·34 | 6724·8 | 2′ 4″ × 2′ 6″ | 8′ 9″ |
| 9″ | 12″ | 24″ | 10·67 | 7682·4 | 2′ 4″ × 2′ 6″ | 9′ 6″ |
| 9½″ | 12½″ | 24″ | 11·83 | 8521·2 | 2′ 4″ × 2′ 6″ | 9′ 6″ |

*This is the best speed for boiler feeding.

# INDEX.

# INDEX.


AIR-PUMP, outline methods of driving, 271
—— and injector condenser, 272—282
—— —— horizontal with buckets, 273
—— —— —— with plunger, 279
—— —— —— Horn's patent, 277
—— —— vertical, 272
—— with surface condenser, Ruston & Proctor, 283
Allen's straight link reversing gear, 230
Atmospheric engine, Newcomen's, 1
Attachment of cylinder to frames of engines, 110, 111

BABCOCK & Wilcox water-tube boilers, 433
Barring apparatus, 414
Bearings, crank shaft, 37—46
Bed-plates, horizontal engines, dimensions of, 19
Belliss & Morcom engines, 351—353a, 353b
Boilers, Cornish, 417
—— —— seating, German, 422
—— —— —— English, 418
—— cylindrical multitubular, 423
—— elephant, 416
—— Lancashire, 419
—— —— seating, 420
—— marine, 431
—— multitubular loco-type, 424
—— vertical 426
—— —— dimensions of, 428
—— —— Cochrane, 426
—— —— Hopwood's, 429
—— —— Tinker, Shenton & Co., 427
—— —— fire-engines, 430
—— —— water-tube, Babcock & Wilcox, 433
—— —— —— Bellville, 434
—— —— —— Clyde, 441
—— —— —— Fleming & Ferguson, 441
Boilers, vertical water-tube, Niclausse, 441
—— —— —— Normand, 441
—— —— —— Stirling, 441
—— water-tube, Thornycroft, 440
—— —— —— Yarrow, 438
Bourne, return connecting-rod engine, 8
Brasses, crank-shaft from actual practice, 41
—— —— pressure on, 41
—— —— result of wear, 39
Brotherhood's radial engine, 9
Bumsted and Chandler's high speed engine, 350

CALCULATIONS for power and steam consumption, 387
Central valve engine, Willans, 9, 348, 349
Chandler's high speed engine, 350
Clearance space with different steam ports, 102
Clyde water-tube boiler, 441
Coal consumption, comparative, 4
Compound engines, beam, 8
—— —— Corliss, 298
—— —— dimensions of, 297
—— —— floor space occupied by, 330
—— —— Hornblower's, 3
—— —— outlines of, 10, 11
—— —— ratio of cylinder volumes, 357
—— —— receivers for, 354
—— —— tandem horizontal, 334
—— —— undertype, 330
Condensers and air pumps,
—— injector, 272—282
—— —— horizontal with buckets, 273
—— —— —— with plunger, 279
—— —— —— Horn's patent, 277
—— —— vertical, 272
surface, Ruston & Proctor, 283

Condensers, Theisen's water cooling apparatus for, 285
Connecting-rods, 62
—— dimensions of, 67—71
Crank-shaft bearings, 37—46
—— brasses, from actual practice, 41
—— —— pressure on, 41
—— —— result of wear, 39
Cranks and crank-shafts, 47—61
—— —— discs, 47—56
Crank pins, 53
—— —— lubrication, 57—58
—— —— particulars from actual practice, 63
Crosby's indicator, 373
Crossheads, 73—80
—— pins, 75—83
Cylinders, attachment to frames, 110
—— clearance space, 101
—— with Corliss gear, 98
—— covers and glands, 112—119
—— feet, 103
—— liners, 104—106
—— mushroom valves, 98
—— ordinary slide valve, 96—108
—— Rider's valve gear, 97—99
—— steam jacket, 104—106
—— thickness of metal, 100
—— triple expansion engines, 98
—— valve chests and covers, 119—124

DARKE'S indicator, 373
Davey, Paxman & Co. double and single cylinder vertical engines, 345
—— compound undertype engines, 347
—— single cylinder undertype engines, 347
Diagrams,
— of engines, 5—10
—— of governors, 133—135
— indicator, 150, 377
—— —— combined, 378, 384
—— —— defects in, 383
—— —— example from actual practice, 379, 382
—— —— measuring of, 373
—— slide valve, 164—192
—— valve gears, 176—179
Dynamometer friction brake, 411

ECCENTRICS, 211—213
Efficiency, coefficient of, 394
Ellipse valve for Meyer's gear, 187
—— —— Rider's gear, 187
Ellipse valve for simple gear, 186
Engines, beam, Boulton & Watt, outline, 5
—— —— compound Wolf, 8
—— —— McNaught, 8
—— Bellis & Morcom, 351—353A, 353B
—— Bourne's, return connecting-rod, 8
—— Bumsted and Chandler's high speed, 350
—— Central valve, Willans', 9, 348
—— —— particulars of, 348, 349
—— Corliss, examples of, 295
—— —— compound examples of, 289
—— compound examples of, 297
—— —— arrangement of cylinders and ports, 354
—— —— tandem, glands and connecting pieces, 356
—— —— ratio of cylinder volumes, 357
—— —— receivers, 358
—— —— vertical for screw steamers, 365
—— —— diagonal for paddle steamers, 368, 370
—— Evans', 2
—— Elder, John, 4
—— by English makers,
Davey, Paxman & Co.:
double and single cylinder vertical, 345
compound undertype, 347
single cylinder undertype, 347
John Fowler & Co.:
compound coupled non-condensing engine, 342
compound undertype, 343
Marshall & Son:
portable, 322—323
vertical, 320, 321
Ransome, Sims & Jefferies:
long stroke horizontal, 318, 319
Robey & Co.:
double cylinder vertical, 339
compound undertype, 340
horizontal girder, 341
Ruston & Proctor:
horizontal self-contained, 324, 325
horizontal, 328, 329
vertical, 326, 327
E. R. & F. Turner:
coupled compound condensing, 338
tandem compound, 334, 335
portable single cylinder, 332
compound, 331

Engines by English makers, Willans' central valve engine, 348
Engine foundations, 314—316
—— frames, 16
—— frictional resistance, 395
—— girder outline of, 6
Engines, general remarks, 13
Engines, bed-plate, outline of, 5
—— dimensions of bed-plates, 19
—— —— girders, 31
—— examples of simple, 292
—— —— compound, 297
—— floor space required by simple, 300, 336
—— —— compound, 301
—— —— tandem compound, 337
—— frames for single, 16—18
—— —— 2 or 3 cylinders, 32
Engine, Hornblower, 3
—— inclined frame paddle, 8
—— —— —— double cylinder, 9
—— —— —— cylinder compound, 9
—— inertia of reciprocating parts, 402
Engines, marine, vertical outline of, 7
—— names of parts, 12
—— oscillating, outline of, 6
—— patterns, cost of, 313
—— radial, outline of, Brotherhood's, 9
—— steeple, outline of, 7
Engine, triple expansion, outline of arrangements of, 10, 11, 366
—— —— —— —— leading particulars of, 362
—— —— —— —— indicator diagrams, 363
—— —— —— —— particulars from actual practice, 364
—— —— —— —— proportions of cylinder volumes, 365
—— Trevitick & Vivian, 2
—— trunk outline of, 7
Engines, vertical outlines, 5
—— —— marine, 7
—— vertical frames small, 33—35
—— —— —— marine, 36
Engine, Watt, 2
—— Wolf, Arthur, 4
Engines, weights of, 302, 311
—— —— connecting rods and cranks, 308
—— —— crankshafts, fly-wheels and bearings, 304
—— —— cylinders and covers, 306, 307
—— —— eccentrics, 309
—— —— foundation bolts, 311
Engines, weights of frames and cross-heads, 302
—— —— governor bracket, 310
—— —— piston and piston rods, 303
—— —— valves and piston rods, 305
Expansion curve of steam, 152
—— —— formula for, 446
—— —— graphic method of drawing, 152

FEED-WATER heater, Dülmen, 290
—— —— Marshall & Son, 289
—— pumps, 286—288, 447
Fleming & Ferguson's boiler, 441
Fly-wheels, 125—132
—— for rope drive, 129, 130
Foundations of engines, 314—316
Fowler, John & Co., compound coupled non-condensing engines, 342
—— —— undertype engines, 343
Frames of engines, 16
Frictional resistance in engines, 395
Friction brake, 411

GLAND'S piston-rod, 112—119
Gooch's reversing gear, 231
Governor-bracket, Rider's, valve-gear, 207—209
Governors, cross-arm, 139, 140
—— Hartnell auto-expansion, 142
—— —— crankshaft, 143
—— Kley's, 138
—— Lauchammer, 141
—— Moore, 147
—— outline diagrams of, 112—119
—— Porter's, 137
—— Proell, 139
—— Turner Hartnell, 145

HARTNELL, auto-expansion governor, 142
—— crankshaft governor, 143
Heaters, feed-water, Marshall & Son, 289
—— —— Dülmen, 290
Hornblower's engine, 3
Horn's condenser, 277

INDICATORS, Crosby's, 373
—— Darke's, 373
—— Richards', 372
—— Thompson's, 372
Indicator diagrams, triple expansion engines, 363
—— diagrams, 151
—— measuring of, 377
—— —— combined, 378
—— —— examples from actual practice, 379—382
—— —— defects in, 383
—— —— general remarks, 150
—— —— gear, examples of, 374—376
—— —— sliding joint for string, 376
Inertia of reciprocating parts, effect of, 402

JACKETS, steam, for cylinders, 104—106

KLEY'S governor, 138
Konig valve gear, 249
Kuchenbecker's gear, 247

LUBRICATOR, crank-shaft, 57, 58

MARSHALL & SON, portable engine, 322—323
—— vertical engine, 321
McNaught's beam engine, 8
Maudslay Sons & Field, water-tube boiler, 434
Maudslay's vertical engine, 7
Meyer's hand adjustment for valve gear, 193
—— slide valves, 156, 187
—— —— —— particulars of, 182—183
Moore's governor, 148—149

NAMES of parts of engines, 12
Newcomen's engine, 1
Niclausse water-tube boiler, 441
Normand water-tube boiler, 441

PATTERNS of engines, cost, 313
Penn's engine outline of, 5—6
—— marine slide valve, 160
Piston rods, 84—95
—— glands, 112—119
—— valves, 163, 222, 223
—— tail-rod guides, 114, 115
Pius Fink, reversing gear, 229
Porter's governor, 137
Power, calculations for and steam consumption, 387
—— —— —— compound engines, 399
Proell's governor, 139
Pulleys, rope grooves, 129, 130
Pumps, feed, 286—288

RANSOME SIMS & JEFFERIES, long-stroke horizontal engines 318, 319
Receivers for compound engines, 358
Reversing-gears, Allan's straight link, 230
—— Gooch's, 231
—— Pius Fink, 229
—— Polonceau, 229
—— Stephenson, 224, 228
—— special, diagrams of, 412
—— Waldegg, 229
Richards' indicator, 372
Rider's valve-gear, 194
—— —— —— cylinder for, 97—99
—— —— —— ellipse, 187
—— —— —— connection to governor, 204, 209
Robey & Co., double cylinder vertical engine, 339
—— compound undertype engine, 340
—— horizontal girder engine, 341
Ruston & Proctor horizontal engine, 328—329
—— —— —— self-contained, 324, 325
—— —— vertical, 326, 327
—— —— surface condenser, 283

SAFETY valves, lever, 442
—— —— Ramsbottom, 443
—— —— dead weight, 444
Slide valves balanced, 162
—— —— —— diagrams, 165
—— —— dimensions of simple, 171—173

Slide valves, double, 180, 181
—— —— explanation of terms, 163, 164
—— —— Garrett, Smith & Co., 158
—— —— Lanz, 158
—— —— Meyer's, 156
—— —— —— ellipse, 186
—— —— —— mushroom and double beat, 234
—— —— particulars of Meyer's, 182, 183
—— —— —— diagram of Meyer's, 184, 185
—— —— Penn, 160
—— —— piston, 163, 222, 223
—— —— Rider's, 157—203
—— —— —— ellipse, 187
—— —— simple, 155
—— —— —— ellipse, 186
—— —— —— diagrams, 165—186
—— —— Trick, 156
—— —— double, diagrams of, 190—192
—— —— Zeuner's diagrams, 166—168
Steam consumption, calculations for, 387
—— temperature and volume of a pound of, 446
—— expansion curve, 152
—— —— graphic method of drawing, 152
Stirling water-tube boiler, 441
Stuffing boxes and glands, 112—119

TAIL rod guides, 114—115
Temperature and volume of steam, 446
Theisen's cooling apparatus, 285
Thompson's indicator, 372
Thornycroft water-tube boiler, 441
Trevithick & Vivian's engine, 2
Triple expansion engines, outlines, 10, 11, 360
—— —— marine engines, diagrams of, 360
—— —— leading dimensions of, 361
—— —— —— —— indicator diagrams, 363
—— —— —— particulars from actual practice, 364
—— —— —— proportions of cylinder volumes, 365
Throttle valve, 132
Turner's horizontal coupled compound engine, 338
Turner's horizontal coupled tandem compound engine, 334, 335
—— —— —— portable single cylinder, 332
—— —— —— compound, 331

UNDERTYPE engines, Turner's, 330

VALVE chests and covers, 119—124
—— gears, American Corliss, 257
—— —— cam motion, 238, 239
—— —— Corliss, details of, 252—270
—— —— diagrams, 176—179
—— —— —— showing defects, 188
—— —— —— Stephenson's link-motion, 224—228
—— —— Farcot, 221
—— —— Frikart, 255
—— —— Gamerith's, with trip action, 250
—— —— Gooch's, 231
—— —— Harris, 253
—— —— Harzer with mushroom valves, 241
—— —— Meyer's, hand-gear, adjusting, 193—195
—— —— with mushroom valves, 233—235
—— —— Polonceau, 229
—— —— Proell, 248
—— —— Recke, 244
—— —— hand adjusting gear, 194
—— —— reversing, 229
—— —— —— Allan, 230
—— —— —— Gooch, 231
—— —— —— Pius Fink, 229
—— —— —— Polonceau, 229
—— —— —— Stephenson's, 224—228
—— —— —— Waldegg, 229
—— —— —— simple, 165
—— —— Sulzer, 251
—— —— with two slides, 174
—— —— Wheelock, 255
—— —— Widnmann mushroom with valves, 242, 243
—— —— classification of, 154
—— —— Corliss, 258—262
—— —— diagrams, 165

Valve chests, dimensions of simple, 171—173
—— —— double slide, 180, 181
—— —— explanation of terms, 163, 164
—— —— Lanz, 158
—— —— Meyer's, 156, 174
—— —— —— particulars of, 182 – 183
—— —— —— diagram of, 184—185
—— —— —— ellipse for, 186
—— —— mushroom and double beat, 240—251
—— —— Rider's, 157—203
—— Rider's, 198
—— —— simple, 155
Valve diagrams, 165, 186, 190
—— ellipse, 186
—— —— Trick, 156
—— —— double slide diagram of, 190—192
—— —— Zeuner's diagram, 176
—— throttle, 132
Volume of a pound of steam at different pressures, 446

WALDEGG, reversing gear, 229
Watt's engine, 2, 5
Weights of engines, 302—311
—— connecting-rod and cranks, 308
Weights of crankshafts, fly-wheels and bearings, 304
—— cylinders and covers, 306, 307
—— eccentrics, 309
—— foundation bolts, 311
—— frames and crossheads, 302
—— governor bracket, 310
—— piston and piston rods, 303
—— valves and valve rods, 305
Weir's feed pumps, 447
Wheels, fly-, 125—132
—— for rope drive, 129, 130
Willans' central valve engine, 9, 348
—— —— —— particulars of, 348, 349
Wolf engine, 4. 8

YARROW'S water-tube boiler, 439

THE END.

BRADBURY, AGNEW, & CO. LD., PRINTERS, LONDON AND TONBRIDGE.

# CROSBY LOCKWOOD & SON'S

LIST OF WORKS

ON

# CIVIL, MECHANICAL, MARINE AND ELECTRICAL ENGINEERING.

A Complete Catalogue of NEW and STANDARD WORKS on MINING and COLLIERY WORKING; ARCHITECTURE and BUILDING; The INDUSTRIAL ARTS, TRADES and MANUFACTURES; CHEMISTRY and CHEMICAL MANUFACTURES; AGRICULTURE, FARMING, GARDENING, AUCTIONEERING, LAND-AGENCY, &c. Post Free on Application.

LONDON:
7, STATIONERS' HALL COURT, LUDGATE HILL, E.C.,
AND
12la Victoria Street, Westminster, S.W.
1910.

# LIST OF WORKS

ON

# CIVIL, MECHANICAL, ELECTRICAL AND MARINE ENGINEERING.

---

**ACETYLENE, LIGHTING BY.** Generators, Burners, and Electric Furnaces. By WILLIAM E. GIBBS, M.E. With 66 Illustrations. Crown 8vo, cloth . . . . . **7/6**

**AËRIAL NAVIGATION.** A Practical Handbook on the Construction of Dirigible Balloons, Aërostats, Aëroplanes, and Airships. By FREDERICK WALKER, C.E., Associate Member of the Aëronautic Institute. Second Edition, thoroughly revised and enlarged. 176 pages, with 128 Illustrations. Crown 8vo, cloth . . . . [*Just Published. Net* **5/0**

THE LAWS OF FLIGHT—AËROSTATICS—AËRODYNAMICS—AËROPLANES IN PRACTICE—MOTIVE POWER—SCREW PROPULSION FOR AËROPLANES AND AIRSHIPS—AIRSHIPS AND DIRIGIBLE AEROSTATS—CONSTRUCTION—AËROPLANES AND AIRSHIPS IN USE—ANTOINETTE MONOPLANE—SANTOS DUMONT MONOPLANE—WRIGHT BIPLANE—FARMAN BIPLANE—MOORE-BRABAZON BIPLANE—DE DION MULTIPLANE—SALMSON AUTOPLANE—VUTTON-HUBER HELICOPTERE.

**AËRIAL OR WIRE-ROPE WAYS.** Their Construction and Management. By A. J. WALLIS-TAYLER, A.M.Inst.C.E. With numerous Illustrations. Demy 8vo . . [*In the Press Price about net* **7/6**

**AIR GAS LIGHTING SYSTEMS.** See PETROL AIR GAS.

**ALTERNATING CURRENTS, THE PRINCIPLES OF.** For Students of Electrical Engineering. By E. T. LARNER, A.I.E.E., of the Engineering Department, G.P.O., London. 144 pages, with 69 Illustrations. Crown 8vo, cloth . . . . . *Net* **3/6**

COMPARISON OF CONTINUOUS AND ALTERNATING CURRENTS—SIMPLE HARMONIC MOTION—VECTORIAL REPRESENTATION—ALTERNATING CURRENT THEORY—CIRCUITS IN SERIES—CIRCUITS IN PARALLEL—ALTERNATING CURRENT POWER.

**ALTERNATING CURRENT MACHINES.** See DYNAMO ELECTRIC MACHINERY.

**ARMATURE WINDINGS OF DIRECT CURRENT DYNAMOS.** Extension and Application of a General Winding Rule. By E. ARNOLD, Engineer, Assistant Professor in Electro-Technics and Machine Design at the Riga Polytechnic School. Translated from the original German by FRANCIS B. DE GRESS, M.E., Chief of Testing Department, Crocker-Wheeler Company. Medium 8vo, 120 pp., with over 140 Illustrations *Net* **12/0**

**AVIATION, THE ART OF.** A Handbook upon Aeroplanes and their Engines, with Notes upon Propellers. By ROBERT W. A. BREWER, A.M.I.C.E., M.I.M.E., Manager to Mr. GRAHAME-WHITE, Member of the Institution of Automobile Engineers, Author of "The Motor Car." Demy 8vo, cloth, 266 pages, with numerous Illustrations and Dimensioned Drawings . . . . . [*Just Published. Net* **10/6**

A COMPARISON BETWEEN MONOPLANES AND BIPLANES—THE FORM OF AN AEROFOIL AND STABILITY—EARLY MODELS—PRINCIPLES OF DESIGN AND ENGINE PROBLEMS—DESCRIPTION OF SOME LEADING ENGINES—PROPELLERS—EFFICIENCY OF PROPELLERS—MATERIALS OF CONSTRUCTION FOR AEROPLANES—DETAILS OF MANUFACTURE—SUCCESSFUL MONOPLANES THE WRIGHT AND VOISIN MACHINES COMPARED—THE FARMAN MACHINE—PROGRESSIVE MONOPLANE RECORDS—THE ART OF FLYING—FUTURE DEVELOPMENT—GLOSSARY OF TERMS AND EXPLANATION OF THE FUNCTIONS OF EACH PART OF A FLYING MACHINE—APPENDIX OF TABLES AND USEFUL DATA.

**BALLOONS—MODEL BALLOONS AND FLYING MACHINES.** With a Short Account of the Progress of Aviation. By J. H. ALEXANDER, M.B., A.I.E.E., Associate of the Scottish Aeronautical Society, Author of "Model Engine Construction," and "Elementary Electrical Engineering." 136 pages, with 46 Illustrations, and 5 sheets of Working Drawings. Crown 8vo, cloth . . . . . *[Just Published. Net* **3/6**

**BEAMS. EXPERIMENTS ON THEIR FLEXURE.** Resulting in the Discovery of New Laws of Failure by Buckling. By ALBERT E. GUY. Medium 8vo, cloth . . . . . *Net* **9/0**

**BLAST FURNACE CALCULATIONS AND TABLES FOR FURNACE MANAGERS AND ENGINEERS.** Containing Rules and Formulæ for Finding the Dimensions and Output Capacity of any Furnace, as well as the regular Outfit of Stoves, Heating Surface, Volume of Air, Tuyere Area, &c., per ton of Iron per day of 24 hours. By JOHN L. STEVENSON. F'cap. 8vo, leather . . . . . *Net* **5/0**

**BOILER AND FACTORY CHIMNEYS.** Their Draught-Power and Stability. With a chapter on "Lightning Conductors." By ROBERT WILSON, A.I.C.E., Author of "A Treatise on Steam Boilers," &c. Crown 8vo, cloth . . . . . **3/6**

**BOILER CONSTRUCTION.** A Practical Handbook for Engineers, Boiler-Makers, and Steam Users. Containing a large Collection of Rules and Data relating to Recent Practice in the Design, Construction, and Working of all Kinds of Stationary, Locomotive, and Marine Steam-Boilers. By WALTER S. HUTTON, Civil and Mechanical Engineer. With upwards of 500 Illustrations. Fourth Edition, carefully Revised, and Enlarged. Medium 8vo. over 680 pages. cloth, strongly bound . . . . **18/0**

HEAT, RADIATION, AND CONDUCTION—NON-CONDUCTING MATERIALS AND COVERINGS FOR STEAM-BOILERS—COMPOSITION, CALORIFIC-POWER AND EVAPORATIVE-POWER OF FUELS—COMBUSTION, FIRING STEAM-BOILERS, PRODUCTS OF COMBUSTION, &C., CHIMNEYS FOR STEAM-BOILERS—STEAM BLAST—FORCED DRAUGHT—FEED-WATER—EFFECT OF HEAT ON WATER—EXPANSION OF WATER BY HEAT—WEIGHT OF WATER AT DIFFERENT TEMPERATURES—CONVECTION—CIRCULATION—EVAPORATION—PROPERTIES OF SATURATED STEAM—EVAPORATIVE POWER OF BOILERS—PRIMING, &C.—WATER-HEATING SURFACES OF STEAM-BOILERS—TRANSMISSION OF HEAT—SMOKE TUBES—EVAPORATIVE POWER AND EFFICIENCY OF BOILERS—WATER-CAPACITY AND STEAM-CAPACITY OF BOILERS—FIRE-GRATES, FIRE BRIDGES, AND FIRE-BARS—POWER OF BOILERS—CYLINDRICAL SHELLS AND FURNACE-TUBES OF BOILERS, &C.—TESTS OF MATERIALS—STRENGTH AND WEIGHT OF BOILER-PLATES—EFFECT OF TEMPERATURE ON METALS—RIVET HOLES—RIVETS—RIVETED JOINTS OF STEAM-BOILERS—CAULKING ENDS OF CYLINDRICAL SHELLS—STAYS FOR BOILERS, &C.—STEAM GENERATORS—DESCRIPTION AND PROPORTIONS OF CORNISH, LANCASHIRE, AND OTHER TYPES OF STATIONARY BOILERS—BOILER-SETTING—MULTI-TUBULAR, LOCOMOTIVE, PORTABLE, MARINE, VERTICAL, AND WATER-TUBE BOILERS—SUPER-HEATERS—COST OF STEAM PRODUCTION—FURNACES FOR REFUSE-FUELS—DESTRUCTORS, &C.—SAFETY-VALVES—STEAM PIPES—STOP-VALVES AND OTHER MOUNTINGS FOR BOILERS—FEED-PUMPS—STEAM PUMPS—FEED-WATER CONSUMPTION—INJECTORS—INCRUSTATION AND CORROSION—FEED-WATER HEATERS—EVAPORATORS—TESTING BOILERS—EVAPORATIVE PERFORMANCES OF STEAM BOILERS: STEAM-BOILER EXPLOSIONS, &C.

**BOILERMAKER'S ASSISTANT.** In Drawing, Templating, and Calculating Boiler Work, &c. By J. COURTNEY, Practical Boilermaker. Edited by D. K. CLARK, C.E. Eighth Edition. Crown 8vo, cloth . **2/0**

**BOILERMAKER'S READY RECKONER.** With Examples of Practical Geometry and Templating for the Use of Platers, Smiths, and Riveters. By John COURTNEY. Edited by D. K. CLARK, M.Inst.C.E. Crown 8vo, cloth . . . . . **4/0**

**BOILERMAKER'S READY RECKONER & ASSISTANT,** being the two previous mentioned volumes bound together in one volume. With Examples of Practical Geometry and Templating, for the Use of Platers, Smiths, and Riveters. By JOHN COURTNEY. Edited by D. K. CLARK, M.Inst.C.E. Fifth Edition, 480 pp., with 140 Illustrations. Crown 8vo, half-bound . . . . . **7/0**

**BOILER MAKING AND PLATING.** A Practical Handbook for Workshop Operations, including an Appendix of Tables. By JOSEPH G. HORNER, A.M.I.M.E. Second Edition. Thoroughly revised and enlarged. 380 pp., with 351 Illustrations. Large Crown 8vo, cloth. *Net* **9/0**

**BOILERS.** Their Strength, Construction, and Economical Working. By R. WILSON, C.E. Fifth Edition. 12mo, cloth . . . . **6/0**

**BOILERS (STEAM).** Their Construction and Management. By R. ARMSTRONG, C.E. Illustrated. Crown 8vo, cloth . . . . **1/6**

**BOILERS (MARINE).** See MARINE ENGINES AND BOILERS.

**BRIDGE CONSTRUCTION IN CAST AND WROUGHT IRON.** A Complete and Practical Treatise on, including Iron Foundations. In Three Parts.—Theoretical, Practical, and Descriptive. By WILLIAM HUMBER A.M.Inst.C.E., and M.Inst.M.E. Third Edition, revised and much improved, with 115 Double Plates (20 of which now first appear in this edition), and numerous Additions to the Text. In 2 vols., imp. 4to, half-bound in morocco . . . . . **£6 16s. 6d.**

"In addition to elevations, plans, and sections, large scale details are given, which very much enhance the instructive work of these illustrations."—*Civil Engineer and Architect's Journal.*

**BRIDGES AND VIADUCTS, IRON AND STEEL.** A Practical Treatise upon their Construction. For the use of Engineers, Draughtsmen, and Students. By FRANCIS CAMPIN, C.E. Crown 8vo, cloth . . . . . **3/6**

**BRIDGES (IRON) OF MODERATE SPAN:** Their Construction and Erection. By H. W. PENDRED. With 40 Illustrations. Crown 8vo, cloth . . . . . **2/0**

**BRIDGES, OBLIQUE.** A Practical and Theoretical Essay. With 13 large Plates. By the late GEORGE WATSON BUCK, M.Inst.C.E. Fourth Edition, revised by his Son, J. H. WATSON BUCK, M.Inst.C.E.; and with the addition of Description to Diagrams for Facilitating the Construction of Oblique Bridges, by W. H. BARLOW, M.Inst.C.E. Royal 8vo, cloth . . . . . **12/0**

"As a guide to the engineer and architect, on a confessedly difficult subject, Mr. Buck's work is unsurpassed."—*Building News.*

**BRIDGES, TUBULAR AND OTHER IRON GIRDER.** Describing the Britannia and Conway Tubular Bridges. With a Sketch of Iron Bridges, &c. By G. D. DEMPSEY, C.E. Crown 8vo, cloth . **2/0**

**CALCULATOR (NUMBER, WEIGHT, AND FRACTIONAL).** Containing upwards of 250,000 Separate Calculations, showing at a Glance the Value at 422 Different Rates, ranging from $\frac{1}{16}$th of a Penny to 20*s.* each, or per cwt., and £20 per ton, of any number of articles consecutively, from 1 to 470. Any number of cwts., qrs., and lbs., from 1 cwt. to 470 cwts. Any number of tons, cwts., qrs., and lbs., from 1 to 1,000 tons. By WILLIAM CHADWICK, Public Accountant. Fourth Edition, Revised and Improved. 8vo, strongly bound . . . . . **18/0**

**CALCULATOR (WEIGHT).** Being a Series of Tables upon a New and Comprehensive Plan, exhibiting at one Reference the exact Value of any Weight from 1 lb. to 15 tons, at 300 Progressive Rates, from 1*d.* to 168*s.* per cwt., and containing 186,000 Direct Answers, which, with their Combinations, consisting of a single addition (mostly to be performed at sight), will afford an aggregate of 10,266,000 Answers; the whole being calculated and designed to ensure correctness and promote despatch. By HENRY HARBEN, Accountant. Sixth Edition, carefully Corrected. Royal 8vo, strongly half-bound . . . . . **£1 5s.**

**CHAIN CABLES AND CHAINS.** Comprising Sizes and Curves of Links, Studs, &c., Iron for Cables and Chains, Chain Cable and Chain Making, Forming and Welding Links, Strength of Cables and Chains, Certificates for Cables, Marking Cables, Prices of Chain Cables and Chains, &c., &c. By THOMAS W. TRAILL, F.E.R.N., M.Inst.C.E., Engineer-Surveyor-in-Chief, Board of Trade, Inspector of Chain Cable and Anchor Proving Establishments, and General Superintendent, Lloyd's Committee on Proving Establishments. With numerous Tables, Illustrations, and Lithographic Drawings. Folio, cloth . . . . . **£2 2s.**

**CIVIL ENGINEERING.** By HENRY LAW, M.Inst.C.E. Including a Treatise on Hydraulic Engineering by G. R. BURNELL, M.Inst.C.E. Seventh Edition, revised, with Large Additions on Recent Practice by D. KINNEAR CLARK, M.Inst.C.E. Crown 8vo, cloth **6/6**

**COKE—MODERN COKING PRACTICE.** Including the Analysis of Materials and Products. A Handbook for those engaged or interested in Coke Manufacture and the recovery of Bye-Products. By T. H. BYROM, F.I.C., F.C.S., Mem. Soc. Chem. Industry; Chief Chemist to the Wigan Coal and Iron Co.; Author of "The Physics and Chemistry of Mining"; and J. E. CHRISTOPHER, Mem. Soc. Chem. Industry. 168 pp., with 109 Illustrations. Demy 8vo, cloth . . . . . [*Just Published. Net* **8/6**

GENERAL CLASSIFICATION OF FUELS—COAL WASHING—SAMPLING AND VALUATION OF COAL, COKE, &C.—CALORIFIC POWER OF COAL AND COKE—COKE OVENS—CHARGING AND DISCHARGING OF COKE OVENS—COOLING AND CONDENSING PLANT—GAS EXHAUSTERS—COMPOSITION AND ANALYSIS OF AMMONIACAL LIQUOR—WORKING UP OF AMMONIACAL LIQUOR—TREATMENT OF WASTE GASES FROM SULPHATE PLANTS—VALUATION OF AMMONIUM SULPHATE—THE DIRECT RECOVERY OF AMMONIA FROM COKE OVEN GASES—SURPLUS GAS FROM COKE OVENS—USEFUL TABLES.

**COMPRESSED AIR WORK AND DIVING.** A Handbook for Engineers, comprising Deep Water Diving and the use of Compressed Air for Sinking Caissons and Cylinders and for Driving Subaqueous Tunnels. By G. W. M. BOYCOTT, Assoc. M.Inst. C.E. 128 pp., with Perspective Drawings and Photographs, Diagrams, Working Drawings and Tables. Medium 8vo, cloth . . . . . *Net* **10/6**

STAGE DECOMPRESSION—THE COMMON DIVING DRESS AND HELMET—ROUQUAYROL-DENAYROUZE APPARATUS—FLEUSS DRESS—THE DIVING BELL—PUMPS—PNEUMATIC CAISSONS AND CYLINDERS—TUNNELLING—BLACKWALL AND ROTHERHITHE TUNNELS—EAST RIVER TUNNELS, NEW YORK—ROCK BLASTING—AIR COMPRESSORS.

**CONDUCTORS FOR ELECTRICAL DISTRIBUTION.** Their Materials and Manufacture, The Calculation of Circuits, Pole-Line Construction, Underground Working, and other Uses. By F. A. C. PERRINE, A.M., D.Sc.; formerly Professor of Electrical Engineering, Leland Stanford, Jr., University; M.Amer.I.E.E. Medium 8vo, 300 pp., fully illustrated, including Folding Plates and Diagrams . . . . . *Net* **20/0**

**CONTINUOUS RAILWAY BRAKES.** A Practical Treatise on the several Systems in Use in the United Kingdom, their Construction and Performance. By M. REYNOLDS. 8vo, cloth . . . . . **9/0**

**CRANES,** the Construction of, and other Machinery for Raising Heavy Bodies for the Erection of Buildings, &c. By J. GLYNN, F.R.S. Crown 8vo, cloth . . . . . **1/6**

**CRUSHING AND GRINDING MACHINERY PRACTICE.** A Handbook on the Machinery used in Crushing and Grinding Operations on all classes of materials. Including also a Glossary of Technical Terms and Bibliography. By THOS. G MARLOW, Grinding, Drying, and Separating Machinery Specialist, Author of "Drying Machinery Practice." With numerous Tables, Plates, and Illustrations . . . . . [*In the Press.*

**CURVES, TABLES OF TANGENTIAL ANGLES AND MULTIPLES.** For Setting-out Curves from 5 to 200 Radius. By A. BEAZELEY, M.Inst.C.E. 7th Edition, Revised. With an Appendix on the use of the Tables for Measuring up Curves. Printed on 50 Cards, and sold in a cloth box, waistcoat-pocket size . . . . . **3/6**

**DRAINAGE OF LANDS, TOWNS AND BUILDINGS.** By G. D. DEMPSEY, C.E. Revised, with large Additions on Recent Practice in Drainage Engineering by D. KINNEAR CLARK, M.Inst.C.E. Fourth Edition. Crown 8vo, cloth . . . . . **4/6**

**DRYING MACHINERY AND PRACTICE.** A Handbook on the Theory and Practice of Drying and Desiccating, with Classified Description of Installations, Machinery, and Apparatus, including also a Glossary of Technical Terms and Bibliography. By THOS. G. MARLOW, Grinding, Drying, and Separating Machinery Specialist. 340 pages, with numerous Tables, Plates, and Illustrations. Medium 8vo, cloth.
[*Just Published.* *Net* **12/6**

**DRYING PROCESSES AND PATENTS.** A complementary volume to "Drying Machinery and Practice." By THOS. G. MARLOW. Describing the various Drying Processes as applied to Sundry Materials, also a Classified Summary of the Patents connected with Drying Processes and Apparati . . . . . [*In the Press*

**DYNAMIC ELECTRICITY AND MAGNETISM, ELEMENTS OF.** A Handbook for Students and Electrical Engineers. By PHILIP ATKINSON, A.M., Ph.D. Crown 8vo, cloth, 417 pp., with 120 Illustrations . . . . . **10/6**

**DYNAMO BUILDING. HOW TO MAKE A DYNAMO.** A Practical Treatise for Amateurs. By ALFRED CROFTS. Crown 8vo, cloth . . . . . **2/0**

**DYNAMO ELECTRIC MACHINERY.** Its Construction, Design and Operation. In Two Volumes (sold separately).

Vol. I.—DIRECT CURRENT MACHINES. By SAMUEL SHELDON, A.M., Ph.D., assisted by HOBART MASON, B.S., E.E. Seventh Edition, Revised. Large crown 8vo, cloth, 288 pp., with 202 Illustrations . . *Net* **12/0**

Vol. II.—ALTERNATING CURRENT MACHINES. By SAMUELS HELDON, A.M., Ph.D., and HOBART MASON, B.S., E.E., and ERICH HAUSMANN, B.S., E.E. Eighth Edition, completely Re-written. Large crown 8vo, cloth. 366 pp., with 236 Illustrations . . . . . *Net* **12/0**

**DYNAMO MANAGEMENT.** A Handybook of Theory and Practice for the Use of Mechanics, Engineers, Students, and others in Charge of Dynamos. By G. W. LUMMIS-PATERSON, Electrical Engineer. Fourth Edition, Revised and Enlarged. 300 pp., with 117 Illustrations. Crown 8vo, cloth . . . . . *Net* **4/6**

**DYNAMO, MOTOR AND SWITCHBOARD CIRCUITS FOR ELECTRICAL ENGINEERS.** A Practical Book dealing with the subject of Direct, Alternating and Polyphase Currents. By WM. R. BOWKER, Consulting Electrical and Street Railway Engineer, Prof. of Physics in the University of Southern California. Second Ed., revised and greatly enlarged. 180 pages, with 130 Illustrations. Medium 8vo, cloth . . . . *Net* **7/6**

DYNAMO AND MOTOR CIRCUITS—STARTING AND STOPPING OF SAME—METHODS OF CHANGING DIRECTION OF ROTATION—SYNCHRONISM—PARALLELING OF ALTERNATORS, &C.—POLYPHASE CIRCUITS—POLYPHASE TRANSMISSION OF POWER—DIPHASE AND TRIPHASE CIRCUITS, &C.—BOOSTERS—EQUALISERS—REVERSIBLE BOOSTERS—STORAGE BATTERIES—END-CELL SWITCHES, &C.—ELECTRIC TRACTION MOTORS—SERIES—PARALLEL CONTROLLERS—CAR WIRING DIAGRAMS—MOTOR VEHICLE CIRCUITS—CANAL HAULAGE ROTARY CONVERTERS, &C.

**DYNAMOS (ALTERNATING AND DIRECT CURRENT).** A Text-book on their Construction for Students, Engineer-Constructors and Electricians-in-Charge. By TYSON SEWELL, A.M.I.E.E., Lecturer and Demonstrator in Electrical Engineering at the Polytechnic, Regent Street, London, author of "The Elements of Electrical Engineering." 328 pp., with over 230 Illustrations. Large crown 8vo, cloth . . . . . *Net* **7/6**

FUNDAMENTAL PRINCIPLES OF DIRECT CURRENTS—THE MAGNETIC FIELD—THE PRODUCTION OF AN ELECTRO-MOTIVE FORCE—FUNDAMENTAL PRINCIPLES OF ALTERNATING CURRENTS—THE ALTERNATING MAGNETIC FIELD—THE CAPACITY OF THE CIRCUIT—BIPOLAR DYNAMO CONSTRUCTION—THEORY OF BIPOLAR MACHINES—BIPOLAR DYNAMO DESIGN—MULTIPOLAR DYNAMO CONSTRUCTION—MULTIPOLAR DYNAMO DESIGN—SINGLE PHASE ALTERNATORS—CONSTRUCTION OF ALTERNATORS—POLYPHASE ALTERNATORS, &C.

**EARTHWORK DIAGRAMS.** Giving graphically the Cubic Contents for different Heights of Banks and Cuttings, either 66 ft. or 100 ft. Chains. By R. A. ERSKINE-MURRAY, A.M.Inst.C.E., and Y. D. KIRTON, A.M.Can.Soc.C.E. On a sheet in a roll. **5/0** *Net*, mounted on card, *Net* **7/6**

**EARTHWORK MANUAL.** By ALEX. J. GRAHAM, C.E. With numerous Diagrams. Second Edition. 18mo, cloth . . . **2/6**

**EARTHWORK TABLES.** Showing the Contents in Cubic Yards of Embankments, Cuttings, &c., of Heights or Depths up to an average of 80 feet. By JOSEPH BROADBENT, C.E., and FRANCIS CAMPIN, C.E. Crown 8vo, cloth . . . . . **5/0**

**EARTHWORK TABLES, HANDY GENERAL.** Giving the Contents in Cubic Yards of Centre and Slopes of Cuttings and Embankments from 3 inches to 80 feet in Depth or Height, for use with either 66 feet Chain or 100 feet Chain. By J. H. WATSON BUCK, M.Inst.C.E. On a Sheet mounted in cloth case . . . . . **3/6**

**ELECTRIC LIGHT.** Its Production and Use. By J. W. URQUHART. Crown 8vo, cloth . . . . . **7/6**

**ELECTRIC LIGHT FITTING.** A Handbook for Working Electrical Engineers. By J. W URQUHART. Crown 8vo, cloth . . **5/0**

**ELECTRIC LIGHT FOR COUNTRY HOUSES.** A Practical Handbook, including Particulars of the Cost of Plant, and Working. By J. H. KNIGHT. Crown 8vo, wrapper . . . . . **1/0**

**ELECTRIC LIGHTING.** By ALAN A. CAMPBELL SWINTON, M.Inst.C.E., M.I.E.E. Crown 8vo, cloth . . . . . **1/6**

**ELECTRIC LIGHTING AND HEATING POCKET BOOK.** Comprising useful Formulæ, Tables, Data, and Particulars of Apparatus and Appliances for the use of Central Stations, Engineers, Contractors, and Engineers-in-Charge. By SYDNEY F. WALKER, R.N., M.I.E.E., M.I.M.E., A.M.Inst.C.E., &c. F'cap 8vo, 448 pp., 270 Diagrams, and 240 Tables. *Net* **7/6**

**ELECTRIC POWER CONDUCTORS.** By WM. A. DEL MAR, A.C.G I., Assoc. Mem. A.I.E.E , Assoc. I.E.E Large crown 8vo, cloth. 336 pages, with numerous Illustrations. . . [*Just published. Net* **9/0**

MATERIALS AND GAUGES—TESTING WIRE AND CABLE—ELECTRICAL PROPERTIES—INSTALLATION—INSULATION AND INSULATED CONDUCTORS—DEPRECIATION AND DETERIORATION—DETERMINATION OF SIZE FOR GIVEN VOLTAGE—DROP AND POWER LOSS—THIRD RAIL CIRCUITS—DETERMINATION OF SIZE FOR GIVEN STRESS IN SPANS — RAIL BONDS — SPECIFICATIONS — TABLES OF INDUCTANCE, REACTANCE, AND CAPACITY, &C.

**ELECTRIC SHIP-LIGHTING.** A Handbook on the Practical Fitting and Running of Ships' Electrical Plant. By J. W. URQUHART. Third edition. Crown 8vc, cloth . . . . . **7/6**

**ELECTRIC-WIRING, DIAGRAMS & SWITCH-BOARDS.** By NEWTON HARRISON, E.E., Instructor of Electrical Engineering in the Newark Technical School. Crown 8vo, cloth . . . . *Net* **5/0**

THE BEGINNING OF WIRING—CALCULATING THE SIZE OF WIRE—A SIMPLE ELECTRIC LIGHT CIRCUIT CALCULATED—ESTIMATING THE MAINS, FEEDERS, AND BRANCHES—USING THE BRIDGE FOR TESTING—THE INSULATION RESISTANCE—WIRING FOR MOTORS—WIRING WITH CLEATS, MOULDING AND CONDUIT—LAYING-OUT A CONDUIT SYSTEM—POWER REQUIRED FOR LAMPS—LIGHTING OF A ROOM—SWITCHBOARDS AND THEIR PURPOSE—SWITCHBOARDS DESIGNED FOR SHUNT AND COMPOUND-WOUND DYNAMOS—PANEL SWITCHBOARDS, STREET RAILWAY SWITCHBOARDS, LIGHTNING ARRESTERS—THE GROUND DETECTOR—LOCATING GROUNDS—ALTERNATING CURRENT CIRCUITS—THE POWER FACTOR IN CIRCUITS—CALCULATION OF SIZES OF WIRE FOR SINGLE, TWO AND THREE-PHASE CIRCUITS.

**ELECTRICAL AND MAGNETIC CALCULATIONS.** For the Use of Electrical Engineers and Artisans, Teacners, Students, and all others interested in the Theory and Application of Electricity and Magnetism. By A. A. ATKINSON, M.S., Professor of Physics and Electricity in Ohio University, Athens, Ohio. Crown 8vo, cloth . . . . *Net* **9/0**

**ELECTRICAL CALCULATIONS (ELEMENTARY).** A Manual of Simple Engineering Mathematics, covering the whole field of Direct Current Calculations, the Basis of Alternating Current Mathematics, Networks and Typical Cases of Circuits, with Appendices on Special Subjects. By T. O'Conor Sloane, A.M., E.M., Ph.D., author of "The Standard Electrical Dictionary." 314 pages, 43 Illustrations. Crown 8vo, cloth . . . . . *Net* **9/0**

Exponential Notation—Mechanics and Physics—Ohm's Law—Resistance—Kirchhoff's Laws—Arrangement of Batteries—Electrical Energy and Power—Bases and Relations of Electrical Units—Thermo-Electricity—Electro-hemistry—Fields of Force—Magnetism—Electro-Magnetic Induction—Capacity and Inductance—Hysteresis and Forcault Currents—Alternating Current—Networks—Demonstrations by Calculus, &c., &c.

**ELECTRICAL DICTIONARY.** A Popular Encyclopædia of Words and Terms Used in the Practice of Electrical Engineering. By T. O'Conor Sloane, A.M., E.M., Ph.D., &c. Fourth Edition, with Appendix. 690 pages and nearly 400 Illustrations. Large crown 8vo, cloth . *Net* **7/6**

**ELECTRICAL ENGINEERING.** A First-Year's Course for Students. By Tyson Sewell, A.I.E.E., Lecturer and Demonstrator in Electrical Engineering at the Polytechnic, Regent Street, London. Fourth Edition, Revised, with additions. Large crown 8vo, cloth. 466 pp., with 277 Illustrations . . . . . *Net* **5/0**

Ohm's Law—Units Employed in Electrical Engineering—Series and Parallel Circuits — Current Density and Potential Drop in the Circuit—The Heating Effect of the Electric Current—The Magnetic Effect of an Electric Current—The Magnetisation of Iron—Electro-Chemistry—Primary Batteries— Accumulators—Indicating Instruments—Ammeters, Voltmeters, Ohmmeters—Electricity Supply Meters—Measuring Instruments, and the Measurement of Electrical Resistance — Measurement of Potential Difference, Capacity, Current Strength, and Permeability—Arc Lamps—Incandescent Lamps — Manufacture and Installation—Photometry — The Continuous Current Dynamo—Direct Current Motors—Alternating Currents—Transformers, Alternators, Synchronous Motors—Polyphase Working—Appendix I., The Three-Wire System—Appendix II., Questions and Answers.

**ELECTRICAL ENGINEERING (ELEMENTARY).** In Theory and Practice. A Class Book for Junior and Senior Students and Working Electricians. By J. H. Alexander. With nearly 200 Illustrations. Crown 8vo, cloth . . . . . *Net* **3/6**

Fundamental Principles—Electrical Currents—Solenoid Coils, Galvanometers— Voltmeters — Measuring Instruments — Alternating Currents — Dynamo Electric Machines—Continuous Current Dynamos—Induction, Static Transformers, Converters—Motors—Primary and Storage Cells—Arc Lamps—Incandescent Lamps—Switches, Fuses, &c.—Conductors and Cables — Electrical Energy Meters—Specifications—Generation and Transmission of Electrical Energy—Generating Stations.

**ELECTRICAL ENGINEERING, GENERAL LECTURES ON.** By C. Proteus Steinmetz, A M., Ph.D. Third edition, compiled and edited by J. Leroy Hayden. 284 pp., with Diagrams. Medium 8vo, cloth. [*Just published.* *Net* **8/6**

**ELECTRICAL TRANSMISSION OF ENERGY.** A Manual for the Design of Electrical Circuits. By Arthur Vaughan Abbott, C.E., Member American Institute of Electrical Engineers, Member American Institute of Mining Engineers, Member American Society of Civil Engineers, Member American Society of Mechanical Engineers, &c. Fourth Edition, entirely Re-written and Enlarged, with numerous Tables, 16 Plates, and nearly 400 other Illustrations. Royal 8vo, 700 pages. Strongly bound in cloth . . . . . *Net* **30/0**

Introduction—The Properties of Wire—The Construction of Aerial Circuits—General Line Work—Electric Railway Circuits—Protection—The Construction of Underground Circuits—Conduits—Cables and Conduit Conductors—Special Railway Circuit—The Interurban Transmission Line—The Third Rail—The Urban Conduit—Electrical Instruments—Methods of Electrical Measurement — Continuous-Current Conductors — The Heating of Conductors—Conductors for Alternating Currents—Series Distribution—Parallel Distribution—Miscellaneous Methods—Polyphase Transmission—The Cost of Production and Distribution.

**ELECTRICAL TRANSMISSION OF ENERGY—THREE-PHASE TRANSMISSION.** A Practical Treatise on the Economic Conditions Governing the Transmission of Electric Energy by Underground and Overhead Wires. By WILLIAM BREW, M.I.E.E., late Consultant Assistant, Dublin Corporation Electricity Supply . . . *[In the Press.*

**ELECTRICITY AS APPLIED TO MINING.** By ARNOLD LUPTON, M.Inst.C.E., M.I.Mech.E., M.I.E.E., late Professor of Coal Mining at the Yorkshire College, Victoria University, Mining Engineer and Colliery Manager; G. D. ASPINALL PARR, M.I.E.E., A.M.I.Mech.E., Associate of the Central Technical College, City and Guilds of London, Head of the Electrical Engineering Department, Yorkshire College, Victoria University; and HERBERT PERKIN, M.I.M.E., Certificated Colliery Manager, Assistant Lecturer in the Mining Department of the Yorkshire College, Victoria University. Second Edition, Revised and Enlarged. Medium 8vo, cloth, 300 pp., with about 170 Illustrations . . . . . *Net* **12/0**

INTRODUCTORY—DYNAMIC ELECTRICITY—DRIVING OF THE DYNAMO—THE STEAM TURBINE—DISTRIBUTION OF ELECTRICAL ENERGY—STARTING AND STOPPING ELECTRICAL GENERATORS AND MOTORS—ELECTRIC CABLES—CENTRAL ELECTRICAL PLANTS—ELECTRICITY APPLIED TO PUMPING AND HAULING—ELECTRICITY APPLIED TO COAL CUTTING—TYPICAL ELECTRIC PLANTS RECENTLY ERECTED—ELECTRIC LIGHTING BY ARC AND GLOW LAMPS—MISCELLANEOUS APPLICATIONS OF ELECTRICITY—ELECTRICITY AS COMPARED WITH OTHER MODES OF TRANSMITTING POWER—DANGERS OF ELECTRICITY.

"The book is a good attempt to meet a growing want, and is well worthy of a place in the mining engineer's library."—*The Electrician.*

**ELECTRICITY IN FACTORIES AND WORKSHOPS: ITS COST AND CONVENIENCE.** A Handbook for Power Producers and Power Users. By A. P. HASLAM, M.I.E.E. 328 pp., with numerous Illustrations. Large crown 8vo, cloth . . . . . *Net* **7/6**

THE ELECTRIC MOTOR AND ITS ACCESSORIES—THE DIRECT CURRENT MOTOR—THE ALTERNATING CURRENT MOTOR—THE STARTING AND SPEED REGULATION OF ELECTRIC MOTORS—THE RATING AND EFFICIENCY OF ELECTRIC MOTORS—THE PROVISION OF ELECTRIC ENERGY—THE COST OF ENERGY AS AFFECTED BY CONDITIONS OF WORKING—THE QUESTION FOR THE SMALL POWER USER—INDEPENDENT GENERATING PLANTS—OIL AND GAS ENGINE PLANTS—INDEPENDENT GENERATING PLANTS—STEAM PLANTS—POWER STATION TARIFFS—THE APPLICATIONS OF ELECTRIC POWER—THE USE OF ELECTRIC POWER IN TEXTILE FACTORIES—ELECTRIC POWER IN PRINTING WORKS—THE USE OF ELECTRIC POWER IN ENGINEERING WORKSHOPS—MISCELLANEOUS APPLICATIONS OF ELECTRIC POWER—THE INSTALLATION OF ELECTRIC MOTORS—THE LIGHTING OF INDUSTRIAL ESTABLISHMENTS.

"The author has done his work well, and produced a book which will rank among the best of its kind."—*Electricity.*

"Altogether the book is one which should do good service to the electrical industry."—*Electrical Industries.*

**ELECTRICITY. A STUDENT'S TEXT-BOOK.** By H. M. NOAD, F.R.S. 650 pp., with 470 Illustrations. Crown 8vo . . **9/0**

**ELECTRICITY, POWER TRANSMITTED BY, AND APPLIED BY THE ELECTRIC MOTOR,** including Electric Railway Construction. By PHILIP ATKINSON, A.M., Ph.D., author of "Elements of Static Electricity." Fourth Edition, Enlarged, Crown 8vo, cloth, 224 pp., with over 90 Illustrations . . . . . *Net* **9/0**

**ELECTRO-PLATING AND ELECTRO-REFINING OF METALS.** Being a new edition of Alexander Watt's "Electro-Deposition." Revised and Largely Re-written by ARNOLD PHILIP, Assoc. R.S.M., B.Sc., A.I.E.E., F.I.C., Principal Assistant to the Admiralty Chemist, formerly Chief Chemist to the Engineering Departments of the India Office, and sometime Assistant Professor of Electrical Engineering and Applied Physics at the Heriot-Watt College, Edinburgh. 700 pp., with numerous Illustrations, Large crown 8vo, cloth . . . . . *Net* **12/6**

**ENGINEERING DRAWING. A WORKMAN'S MANUAL.** By JOHN MAXTON, Instructor in Engineering Drawing, Royal Naval College, Greenwich. Eighth Edition. 300 Plates and Diagrams. Crown 8vo, cloth . . . . . **3/6**

"A copy of it should be kept for reference in every drawing office."—*Engineering.*

**ENGINEERING ESTIMATES, COSTS, AND ACCOUNTS.**
A Guide to Commercial Engineering. With numerous examples of Estimates and Costs of Millwright Work, Miscellaneous Productions, Steam Engines and Steam Boilers; and a Section on the Preparation of Costs Accounts. By A GENERAL MANAGER. Second Edition. 8vo, cloth . . . . . **12/0**

"The information is given in a plain, straightforward manner, and bears throughout evidence of the intimate practical acquaintance of the author with every phase of commercial engineering."—*Mechanical World.*

**ENGINEERING PROGRESS (1863-6).** By WM. HUMBER, A.M.Inst.C.E. Complete in Four Vols. Containing 148 Double Plates, with Portraits and Copious Descriptive Letterpress. Imp. 4to, half-morocco. Price, complete, **£12 12s.**; or each Volume sold separately at **£3 3s.** per Volume. *Descriptive List of Contents on application.*

**ENGINEER'S AND MILLWRIGHT'S ASSISTANT.** A Collection of Useful Tables, Rules, and Data. By WILLIAM TEMPLETON. Eighth Edition, with Additions. 18mo, cloth . . . . . **2/6**

"A deservedly popular work. It should be in the 'drawer' of every mechanic."—*English Mechanic.*

**ENGINEER'S HANDBOOK.** A Practical Treatise on Modern Engines and Boilers, Marine, Locomotive, and Stationary. And containing a large collection of Rules and Practical Data relating to Recent Practice in Designing and Constructing all kinds of Engines, Boilers, and other Engineering work. The whole constituting a comprehensive Key to the Board of Trade and other Examinations for Certificates of Competency in Modern Mechanical Engineering. By WALTER S. HUTTON, Civil and Mechanical Engineer, Author of "The Works' Manager's Handbook for Engineers," &c. With upwards of 420 Illustrations. Sixth Edition, Revised and Enlarged. Medium 8vo, nearly 560 pp., strongly bound . . . . . **18/0**

"A mass of information set down in simple language, and in such a form that it can be easily referred to at any time. The matter is uniformly good and well chosen, and is greatly elucidated by the illustrations. The book will find its way on to most engineers' shelves, where it will rank as one of the most useful books of reference."—*Practical Engineer.*

"Full of useful information, and should be found on the office shelf of all practical engineers."—*English Mechanic.*

**ENGINEER'S, MECHANIC'S, ARCHITECT'S, BUILDER'S, &c., TABLES AND MEMORANDA.** Selected and Arranged by FRANCIS SMITH. Seventh Edition, Revised, including ELECTRICAL TABLES, FORMULÆ, and MEMORANDA. Waistcoat-pocket size, limp leather . . . . . **1/6**

"The best example we have ever seen of 270 pages of useful matter packed into the dimensions of a card-case."—*Building News.*

**ENGINEER'S YEAR-BOOK FOR 1910.** Comprising Formulæ, Rules, Tables, Data and Memoranda. Forming a Compendium of the Modern Practice of Civil, Mechanical, Electrical, Marine and Mine Engineering. By H. R. KEMPE, M.Inst.C.E., Electrician to the Post Office, Formerly Principal Staff Engineer, Engineer-in-Chief's Office, General Post Office, London, Author of "A Handbook of Electrical Testing," "The Electrical Engineer's Pocket-Book," &c. With the Collaboration of Eminent Specialists. 1,200 pp., with 1,000 Illustrations, specially engraved for the work. Crown 8vo, leather. [*Just Published.* **8/0**

"Kempe's Year-Book really requires no commendation. Its sphere of usefulness is widely known, and it is used by engineers the world over."—*The Engineer.*

"The volume is distinctly in advance of most similar publications in this country."—*Engineering.*

**ENGINEMAN'S POCKET COMPANION,** and Practical Educator for Enginemen, Boiler Attendants, and Mechanics. By MICHAEL REYNOLDS. With 45 Illustrations and numerous Diagrams. Fifth Edition. Royal 18mo, strongly bound for pocket wear . . . . . **3/6**

**EXCAVATION (EARTH AND ROCK).** A Practical Treatise by CHARLES PRELINI, C.E. 365 pp., with Tables, many Diagrams and Engravings. Royal 8vo, cloth . . . . . *Net* **16/0**

**FACTORY ACCOUNTS: their PRINCIPLES & PRACTICE.** A Handbook for Accountants and Manufacturers. By E. GARCKE and J. M. FELLS. Crown 8vo, cloth . . . . . **7/6**

**FOUNDATIONS AND CONCRETE WORKS.** With Practical Remarks on Footings, Planking, Sand and Concrete, Béton, Pile-driving, Caissons, and Cofferdams. By E. DOBSON. Crown 8vo . . . **1/6**

**FUEL, ITS COMBUSTION AND ECONOMY.** Consisting of an Abridgment of "A Treatise on the Combustion of Coal and the Prevention of Smoke." By C. W. WILLIAMS, A.Inst.C.E. With extensive Additions by D. KINNEAR CLARK, M.Inst.C.E. Fourth Edition. Crown 8vo, cloth . . . . . **3/6**

**FUELS: SOLID, LIQUID, AND GASEOUS.** Their Analysis and Valuation. For the use of Chemists and Engineers. By H. J. PHILLIPS, F.C.S., formerly Analytical and Consulting Chemist to the Great Eastern Railway. Fourth Edition. Crown 8vo, cloth . . . . . **2/0**

**GAS AND OIL ENGINE MANAGEMENT.** A Practical Guide for Users and Attendants, being Notes on Selection, Construction, and Management. By M. POWIS BALE, M.Inst.C.E., M.I.Mech.E. Author of "Woodworking Machinery," &c. Second Edition, with an additional Chapter on Gas Producers. Crown 8vo, cloth . . . . . *Net* **3/6**

SELECTING AND FIXING A GAS ENGINE—PRINCIPLES OF WORKING, &C.—FAILURES AND DEFECTS—VALVES, IGNITION, PISTON RINGS, &C.—OIL ENGINES—GAS PRODUCERS—RULES, TABLES, &C.

**GAS ENGINE, A HANDBOOK ON THE.** A Practical Treatise on the Design, Construction and Running of Internal Combustion Engines. By HERMAN HAEDER, Civil Engineer, Wiesbaden. Translated from the German, with the addition of numerous useful tables and other matter by WILLIAM M. HUSKISSON, A.M.I.E.E. About 200 pages, with 500 Illustrations and Tables. Small 4to . . . . . [*In preparation.*

**GAS ENGINEER'S POCKET-BOOK.** Comprising Tables Notes and Memoranda relating to the Manufacture, Distribution, and Use of Coal Gas and the Construction of Gas Works. By H. O CONNOR, A.M.Inst. C.E. Third Edition, Revised. Crown 8vo, leather . . *Net* **10/6**

**GAS ENGINEERING.** See PRODUCER GAS PRACTICE AND INDUSTRIAL GAS ENGINEERING.

**GAS-ENGINE HANDBOOK.** A Manual of Useful Information for the Designer and the Engineer. By E. W. ROBERTS, M.E. With Forty Full-page Engravings. Small F'cap. 8vo, leather. . *Net* **8/6**

**GAS ENGINES.** With Appendix describing a Recent Engine with Tube Igniter. By T. M. GOODEVE, M.A. Crown 8vo, cloth . **2/6**

**GAS ENGINES.** See also INTERNAL COMBUSTION ENGINES.

**GAS-ENGINES AND PRODUCER-GAS PLANTS.** A Treatise setting forth the Principles of Gas Engines and Producer Design, the Selection and Installation of an Engine, the Care of Gas Engines and Producer-Gas Plants, with a Chapter on Volatile Hydrocarbon and Oil Engines. By R. E. MATHOT, M.E. Translated from the French. With a Preface by DUGALD CLERK, M.Inst.C.E., F.C.S. Medium 8vo, cloth, 310 pages, with about 150 Illustrations . . . . . *Net* **12/0**

MOTIVE POWER AND COST OF INSTALLATION—SELECTION OF AN ENGINE—INSTALLATION OF AN ENGINE—FOUNDATION AND EXHAUST—WATER CIRCULATION—LUBRICATION—CONDITIONS OF PERFECT OPERATION—HOW TO START AN ENGINE—PRECAUTIONS—PERTURBATIONS IN THE OPERATION OF ENGINES—PRODUCER-GAS ENGINES—PRODUCER-GAS—PRESSURE GAS-PRODUCERS—SUCTION GAS-PRODUCERS—OIL AND VOLATILE HYDROCARBON ENGINES—THE SELECTION OF AN ENGINE.

**GAS MANUFACTURE, CHEMISTRY OF.** A Practical Manual for the Use of Gas Engineers, Gas Managers and Students. By HAROLD M. ROYLE, F.C.S., Chief Chemical Assistant at the Becton Gas Works. Demy 8vo, cloth. 340 pages, with numerous Illustrations and Coloured Plate . . . . . *Net* **12/6**

PREPARATION OF STANDARD SOLUTIONS—ANALYSIS OF COALS—DESCRIPTION OF VARIOUS TYPES OF FURNACES—PRODUCTS OF CARBONISATION AT VARIOUS TEMPERATURES—ANALYSIS OF CRUDE GAS—ANALYSIS OF LIME—ANALYSIS OF AMMONIACAL LIQUOR—ANALYTICAL VALUATION OF OXIDE OF IRON—ESTIMATION OF NAPTHALIN—ANALYSIS OF FIRE-BRICKS AND FIRE-CLAY—ART OF PHOTOMETRY—CARBURETTED WATER GAS—APPENDIX CONTAINING STATUTORY AND OFFICIAL REGULATIONS FOR TESTING GAS, VALUABLE EXCERPTS FROM VARIOUS IMPORTANT PAPERS ON GAS CHEMISTRY, USEFUL TABLES, MEMORANDA, &C.

**GAS WORKS.** Their Construction and Arrangement, and the Manufacture and Distribution of Coal Gas. By S. HUGHES, C.E. Ninth Edition. Revised, with Notices of Recent Improvements by HENRY O'CONNOR, A.M.Inst.C.E. Crown 8vo, cloth . . . . . **6/0**

**GEOMETRY.** For the Architect, Engineer, and Mechanic. By E. W. TARN, M.A., Architect. 8vo, cloth . . . . . **9/0**

**GEOMETRY FOR TECHNICAL STUDENTS.** By E. H. SPRAGUE, A.M.Inst.C.E. Crown 8vo, cloth . . . . . *Net* **1/0**

**GEOMETRY OF COMPASSES.** By OLIVER BYRNE. Coloured Plates. Crown 8vo, cloth . . . . . **3/6**

**GUNNERY.** See RECOIL OF GUNS.

**HEAT, EXPANSION OF STRUCTURES BY.** By JOHN KEILY, C.E. Crown 8vo, cloth . . . . . **3/6**

**HOISTING MACHINERY.** Including the Elements of Crane Construction and Descriptions of the Various Types of Cranes in Use. By JOSEPH HORNER, A.M.I.M.E. Crown 8vo, cloth, with 215 Illustrations, including Folding Plates . . . . . *Net* **7/6**

**HYDRAULIC MANUAL.** Consisting of Working Tables and Explanatory Text. Intended as a Guide in Hydraulic Calculations and Field Operations. By LOWIS D'A. JACKSON. Fourth Edition, Enlarged. Large crown 8vo, cloth . . . . . **16/0**

**HYDRAULIC POWER ENGINEERING.** A Practical Manual on the Concentration and Transmission of Power by Hydraulic Machinery. By G. CROYDON MARKS, A.M.Inst.C.E. Second Edition, Enlarged, with about 240 Illustrations. 8vo, cloth . . . . . *Net* **10/6**

SUMMARY OF CONTENTS:—PRINCIPLES OF HYDRAULICS—THE FLOW OF WATER—HYDRAULIC PRESSURES—MATERIAL—TEST LOAD—PACKING FOR SLIDING SURFACES—PIPE JOINTS—CONTROLLING VALVES—PLATFORM LIFTS—WORKSHOP AND FOUNDRY CRANES—WAREHOUSE AND DOCK CRANES—HYDRAULIC ACCUMULATORS—PRESSES FOR BALING AND OTHER PURPOSES—SHEET METAL WORKING AND FORGING MACHINERY—HYDRAULIC RIVETERS—HAND AND POWER PUMPS—STEAM PUMPS—TURBINES—IMPULSE TURBINES—REACTION TURBINES—DESIGN OF TURBINES IN DETAIL—WATER WHEELS—HYDRAULIC ENGINES—RECENT ACHIEVEMENTS—PRESSURE OF WATER—ACTION OF PUMPS, &c.

**HYDRAULIC TABLES, CO-EFFICIENTS, & FORMULÆ.** For Finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers. With New Formulæ, Tables, and General Information on Rain-fall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. By JOHN NEVILLE, C.E., M.R.I.A. Third Edition, revised, with additions. Numerous Illustrations. Crown 8vo, cloth . . . **14/0**

**INTERNAL COMBUSTION ENGINES.** Their Theory, Construction, and Operation. By ROLLA C. CARPENTER, M.M.E., LL.D., and H. DIEDERICHS, M.E., Professors of Experimental Engineering, Sibley College, Cornell University. 610 pages, with 373 Illustrations. Medium 8vo, cloth . . . . . *Net* **21/0**

INTRODUCTION, DEFINITIONS AND CLASSIFICATIONS, INDICATED AND BRAKE HORSE-POWER—THERMODYNAMICS OF THE GAS ENGINE—THEORETICAL COMPARISON OF VARIOUS TYPES OF INTERNAL COMBUSTION ENGINES—THE VARIOUS EVENTS OF THE CONSTANT-VOLUME AND CONSTANT-PRESSURE CYCLE AS MODIFIED BY PRACTICAL CONDITIONS—THE TEMPERATURE ENTROPY DIAGRAM APPLIED TO THE GAS ENGINE—COMBUSTION—GAS ENGINE FUELS, THE SOLID FUELS, GAS PRODUCERS—THE GAS-ENGINE FUELS, LIQUID FUELS, CARBURETERS AND VAPORISERS—GAS ENGINE FUELS, THE GAS FUELS, THE FUEL MIXTURE EXPLOSIBILITY, PRESSURE, AND TEMPERATURE—THE HISTORY OF THE GAS ENGINE—MODERN TYPES OF INTERNAL COMBUSTION ENGINES—GAS ENGINE AUXILIARIES, IGNITION, MUFFLERS, AND STARTING APPARATUS—REGULATION OF INTERNAL COMBUSTION ENGINES—THE ESTIMATION OF POWER OF GAS ENGINES—METHODS OF TESTING INTERNAL COMBUSTION ENGINES—THE PERFORMANCE OF GAS ENGINES AND GAS PRODUCERS—COST OF INSTALLATION AND OF OPERATION.

**IRON AND METAL TRADES' COMPANION.** For Expeditiously Ascertaining the Value of any Goods bought or sold by Weight, from 1s. per cwt. to 112s. per cwt., and from one farthing per pound to one shilling per pound. By THOMAS DOWNIE. Strongly bound in leather, 396 pp. . . . . **9/0**

**IRON AND STEEL.** A Work for the Forge, Foundry, Factory, and Office. Containing ready, useful, and trustworthy Information for Iron-masters and their Stock-takers; Managers of Bar, Rail, Plate, and Sheet Rolling Mills; Iron and Metal Founders; Iron Ship and Bridge Builders; Mechanical, Mining, and Consulting Engineers; Architects, Contractors, Builders, &c. By CHARLES HOARE, Author of "The Slide Rule," &c. Ninth Edition. 32mo, leather . . . . . **6/0**

**IRON AND STEEL CONSTRUCTIONAL WORK,** as applied to Public, Private, and Domestic Buildings. By FRANCIS CAMPIN, C.E. Crown 8vo, cloth . . . . . **3/6**

**IRON & STEEL GIRDERS.** A Graphic Table for facilitating the Computation of the Weights of Wrought Iron and Steel Girders, &c., for Parliamentary and other Estimates. By J. H. WATSON BUCK, M.Inst.C.E. On a Sheet . . . . . **2/6**

**IRON-PLATE WEIGHT TABLES.** For Iron Shipbuilders, Engineers, and Iron Merchants. Containing the Calculated Weights of upwards of 150,000 different sizes of Iron Plates from 1 foot by 6 in. by ¼ in. to 10 feet by 5 feet by 1 in. Worked out on the Basis of 40 lbs. to the square foot of Iron of 1 inch in thickness. By H. BURLINSON and W. H. SIMPSON. 4to, half-bound . . . . . **£1 5s.**

**IRRIGATION (PIONEER).** A Manual of Information for Farmers in the Colonies. By E. O. MAWSON, M.Inst.C.E., Executive Engineer, Public Works Department, Bombay. With Chapters on Light Railways by E. R. CALTHROP, M.Inst.C.E., M.I.M.E. With Plates and Diagrams. Demy 8vo, cloth . . . . . *Net* **10/6**

VALUE OF IRRIGATION, AND SOURCES OF WATER SUPPLY—DAMS AND WEIRS—CANALS—UNDERGROUND WATER—METHODS OF IRRIGATION—SEWAGE IRRIGATION—IMPERIAL AUTOMATIC SLUICE GATES—THE CULTIVATION OF IRRIGATED CROPS, VEGETABLES, AND FRUIT TREES—LIGHT RAILWAYS FOR HEAVY TRAFFIC—USEFUL MEMORANDA AND DATA.

**LATHE PRACTICE.** A Complete and Practical Work on the Modern American Lathe. By OSCAR E. PERRIGO, M.E., Author of "Modern Machine Shop Construction, Equipment, and Management," &c. Medium 8vo, 424 pp., 315 Illustrations. Cloth . . . *Net* **12/0**

HISTORY OF THE LATHE UP TO THE INTRODUCTION OF SCREW THREADS—ITS DEVELOPMENT SINCE THE INTRODUCTION OF SCREW THREADS—CLASSIFICATION OF LATHES—LATHE DESIGN: THE BED AND ITS SUPPORTS—THE HEAD-STOCK CASTING, THE SPINDLE, AND SPINDLE-CONE—THE SPINDLE BEARINGS, THE BACK GEARS, AND THE TRIPLE-GEAR MECHANISM—THE TAIL STOCK, THE CARRIAGE, THE APRON, &C.—TURNING RESTS, SUPPORTING RESTS, SHAFT STRAIGHTENERS, &C.—LATHE ATTACHMENTS—RAPID CHANGE GEAR MECHANISM—LATHE TOOLS, HIGH-SPEED STEEL, SPEEDS AND FEEDS, POWER FOR CUTTING TOOLS, &C.—TESTING A LATHE—LATHE WORK—ENGINE LATHES—HEAVY LATHES—HIGH-SPEED LATHES—SPECIAL LATHES—REGULAR TURRET LATHES—SPECIAL TURRET LATHES—ELECTRICALLY-DRIVEN LATHES.

**LATHE-WORK.** A Practical Treatise on the Tools, Appliances, and Processes employed in the Art of Turning. By PAUL N. HASLUCK. Eighth Edition. Crown 8vo, cloth . . . . . **5/0**

"We can safely recommend the work to young engineers. To the amateur it will simply be invaluable."—*Engineer.*

**LAW FOR ENGINEERS AND MANUFACTURERS.** See EVERY MAN'S OWN LAWYER. A Handybook of the Principles of Law and Equity. By a Barrister. Forty-seventh (1910) Edition, Revised and Enlarged, including Abstracts of the Legislation of 1909 of especial interest to Engineering Firms and Manufacturers, such as the Housing and Town Planning Act; the Development and Road Improvement Act; the Trade Board Act; the Labour Exchanges Act, and many other recent Acts. Large crown 8vo, cloth, 838 pages . . . . [*Just published. Net* **6/8**

"No Englishman ought to be without this book."—*Engineer.*

"Ought to be in every business establishment and all libraries."—*Sheffield Post.*

"It is a complete code of English Law written in plain language, which all can understand. . . . Should be in the hands of every business man, and all who wish to abolish lawyers' bills."—*Weekly Times.*

"A useful and concise epitome of the law, compiled with considerable care."—*Law Magazine.*

**LEVELLING, PRINCIPLES AND PRACTICE OF.** Showing its Application to Purposes of Railway and Civil Engineering in the Construction of Roads; with Mr. TELFORD'S Rules for the same. By FREDERICK W. SIMMS, M.Inst.C.E. Ninth Edition, with LAW'S Practical Examples for Setting-out Railway Curves, and TRAUTWINE'S Field Practice of Laying-out Circular Curves. With 7 Plates and numerous Woodcuts. 8vo . . . . . **8/6**

"The publishers have rendered a substantial service to the profession, especially to the younger members, by bringing out the present edition of Mr. Simms's useful work."—*Engineering.*

**LIGHTNING CONDUCTORS, MODERN.** An Illustrated Supplement to the Report of the Lightning Research Committee of 1905, also the Phœnix Fire Office 1910 Rules, with Notes as to the Methods of Protection, and Specifications. By KILLINGWORTH HEDGES, M.Inst.C.E., M.I.E.E., Honorary Secretary to the Lightning Research Committee. Second edition, with additions. 132 pages with Illustrations. Medium 8vo, cloth. [*Just published. Net* **6/6**

"The work now appears with some additions that noticeably enhance its value."—*Scotsman.*

"The most important innovation is the Phœnix Co.'s Rules. There are several new illustrations, including a remarkable picture of the interior of Barham Church, which was struck with lightning on February 8, 1906."—*Ironmonger.*

"Some 77 illustrations are included, many of which are of a particularly interesting nature, especially those showing the effect of lightning strokes on protected and unprotected buildings."—*Hardware Trade Journal.*

**LOCOMOTIVE ENGINE.** The Autobiography of an old Locomotive Engine. By ROBERT WEATHERBURN, M.I.M.E. With Illustrations and Portraits of GEORGE and ROBERT STEPHENSON. Crown 8vo, cloth. *Net* **2/6**

**LOCOMOTIVE ENGINE DEVELOPMENT.** A Popular Treatise on the Gradual Improvements made in Railway Engines between 1803 and 1903. By CLEMENT C. STRETTON, C.E. Sixth Edition, Revised and Enlarged. Crown 8vo, cloth . . . . . *Net* **4/6**

**LOCOMOTIVE ENGINE DRIVING.** A Practical Manual for Engineers in Charge of Locomotive Engines. By MICHAEL REYNOLDS, M.S.E. Twelfth Edition. Crown 8vo, cloth, **3/6**; cloth boards **4/6**

**LOCOMOTIVE ENGINES.** A Rudimentary Treatise on. By G. D. DEMPSEY, C.E. With large Additions treating of the Modern Locomotive, by D. K. CLARK, M.Inst.C.E. With Illustrations. Crown 8vo, cloth **3/0**

**LOCOMOTIVE (MODEL) ENGINEER,** Fireman and Engine Boy. Comprising a Historical Notice of the Pioneer Locomotive Engine and their Inventors. By MICHAEL REYNOLDS. Crown 8vo, cloth, **3/6** cloth boards . . . . . **4/6**

**LOCOMOTIVES, THE APPLICATION OF HIGHLY SUPERHEATED STEAM TO.** See STEAM.

**MACHINERY, DETAILS OF.** Comprising Instructions for the Execution of various Works in Iron in the Fitting Shop, Foundry, and Boiler Yard. By FRANCIS CAMPIN, C.E. Crown 8vo, cloth . . **3/0**

**MACHINE SHOP TOOLS.** A Practical Treatise describing in every detail the Construction, Operation and Manipulation of both Hand and Machine Tools; being a work of Practical Instruction in all Classes of Modern Machine Shop Practice, including Chapters on Filing, Fitting and Scraping Surfaces; on Drills, Reamers, Taps and Dies; the Lathe and its Tools; Planers, Shapers and their Tools; Milling Machines and Cutters; Gear Cutters and Gear Cutting; Drilling Machines and Drill Work; Grinding Machines and their Work; Hardening and Tempering, Gearing, Belting, and Transmission Machinery; Useful Data and Tables. By W. H. VAN DERVOORT, M.E. Illustrated by 673 Engravings. Medium 8vo. *Net* **21/0**

**MAGNETOS FOR AUTOMOBILISTS:** How Made and How Used. A Handbook of Practical Instruction in the Manufacture and Adaptation of the Magneto to the needs of the Motorist. By S. R. BOTTONE, late of the Collegio del Carmine, Turin; Author of "The Dynamo," "Ignition Devices," &c. Second Edition, Enlarged. 118 pages. With 52 Illustrations. Crown 8vo, cloth . . . . . *Net* **2/0**

**MARINE ENGINEERING.** An Elementary Manual for Young Marine Engineers and Apprentices. By J. S. BREWER. Crown 8vo, cloth. **1/6**

**MARINE ENGINEER'S GUIDE** to Board of Trade Examinations for Certificates of Competency. Containing all Latest Questions to Date, with Simple, Clear, and Correct Solutions; 302 Elementary Questions with Illustrated Answers, and Verbal Questions and Answers; complete Set of Drawings with Statements completed. By A. C. WANNAN, C.E., Consulting Engineer, and E. W. I. WANNAN, M.I.M.E., Certificated First Class Marine Engineer. With numerous Engravings. Fourth Edition, Enlarged. 500 pages. Large crown 8vo, cloth . . . . . *Net* **10/6**

**MARINE ENGINEER'S POCKET-BOOK.** Containing latest Board of Trade Rules and Data for Marine Engineers. By A. C. WANNAN. Fifth Edition. 186 pages, Illustrated. Square 18mo, with thumb Index, leather . . . . . *[Just Published. Net* **4/6**

**MARINE ENGINES AND BOILERS.** Their Design and Construction. A Handbook for the Use of Students, Engineers, and Naval Constructors. Based on the Work "Berechnung und Konstruktion der Schiffsmaschinen und Kessel," by Dr. G. BAUER, Engineer-in-Chief of the Vulcan Shipbuilding Yard, Stettin. Translated from the Second German Edition by E. M. DONKIN, and S. BRYAN DONKIN, A.M.I.C.E. Edited by LESLIE S. ROBERTSON, Secretary to the Engineering Standards Committee, M.I.C.E., M.I.M.E., M.I.N.A., &c. With numerous Illustrations and Tables. Medium 8vo, cloth . . . . . *Net* **25/0**

SUMMARY OF CONTENTS:—PART I.—MAIN ENGINES—DETERMINATION OF CYLINDER DIMENSIONS—THE UTILISATION OF STEAM IN THE ENGINE—STROKE OF PISTON—NUMBER OF REVOLUTIONS—TURNING MOMENT—BALANCING OF THE MOVING PARTS—ARRANGEMENT OF MAIN ENGINES—DETAILS OF MAIN ENGINES—THE CYLINDER—VALVES—VARIOUS KINDS OF VALVE GEAR—PISTON RODS—PISTONS—CONNECTING ROD AND CROSSHEAD—VALVE GEAR RODS—BED PLATES—ENGINE COLUMNS—REVERSING AND TURNING GEAR. PART II.—PUMPS—AIR, CIRCULATING FEED, AND AUXILIARY PUMPS. PART III.—SHAFTING, RESISTANCE OF SHIPS, PROPELLERS—THRUST SHAFT AND THRUST BLOCK—TUNNEL SHAFTS AND PLUMMER BLOCKS—SHAFT COUPLINGS—STERN TUBE—THE SCREW PROPELLER—CONSTRUCTION OF THE SCREW. PART IV.—PIPES AND CONNECTIONS—GENERAL REMARKS, FLANGES, VALVES, &c.—UNDER WATER FITTINGS—MAIN STEAM, AUXILIARY STEAM, AND EXHAUST PIPING—FEED WATER, BILGE, BALLAST AND CIRCULATING PIPES. PART V.—STEAM BOILERS—FIRING AND THE GENERATION OF STEAM—CYLINDRICAL BOILERS.—LOCOMOTIVE BOILERS—WATER-TUBE BOILERS—SMALL TUBE WATER-TUBE BOILERS—SMOKE BOX—FUNNEL AND BOILER LAGGING—FORCED DRAUGHT—BOILER FITTINGS AND MOUNTINGS. PART VI.—MEASURING INSTRUMENTS. PART VII.—VARIOUS DETAILS—BOLTS, NUTS, SCREW THREADS, &c.—PLATFORMS, GRATINGS, LADDERS—FOUNDATIONS—SEATINGS—LUBRICATION—VENTILATION OF ENGINE ROOMS—RULES FOR SPARE GEAR. PART VIII.—ADDITIONAL TABLES.

**MARINE ENGINES AND STEAM VESSELS.** By R. MURRAY, C.E. Eighth Edition, thoroughly Revised, with Additions by the Author and by GEORGE CARLISLE, C.E. Crown 8vo, cloth . . **4/6**

**MARINE STEAM TURBINE.** A practical Description of the Parsons Marine Turbine as presently con tructed, fitted, and run, intended for the use of Students, Marine Engineers, Superintendent Engineers, Draughtsmen, Works' Managers, Foremen Engineers, and others. By J. W. SOTHERN, Member, Institute of Engineers and Shipbuilders in Scotland; Hon. Member, West of Scotland Foremen Engineers' and Draughtsmen's Association; Principal, Sothern's Marine Engineering College, Glasgow; Member, Association of Engineering Teachers. Previous editions translated into the French, German, Spanish, and Dutch languages. Illustrated by over 180 Diagrams, Photographs, and Detail Drawings. Third edition, Re-written and greatly enlarged. Medium 8vo, cloth . . . . . *Net* **12/6**

**MARINE STEAM TURBINES.** A Handbook for the use of Students, Engineers, and Naval Constructors. Based on the work "Schiffsturbinen." By Dr. G. BAUER, Engineer-in-Chief of the Vulcan Shipbuilding Yard, Stettin, and O. LASCHE, Engineer-in-Chief of the Steam Turbine Works of the A.E.G., Berlin. Translated from the German by M. G. S. SWALLOW. With 104 Illustrations and Tables *[In preparation.*

**MASONRY DAMS FROM INCEPTION TO COMPLETION.** Including numerous Formulæ, Forms of Specification and Tender, Pocket Diagram of Forces, &c. For the use of Civil and Mining Engineers. By C. F. COURTNEY, M.Inst.C.E. 8vo, cloth . . . . . **9/0**

**MASTING, MAST-MAKING, AND RIGGING OF SHIPS.** Also Tables of Spars, Rigging, Blocks; Chain, Wire, and Hemp Ropes, &c., relative to every class of vessels. By R. KIPPING. Crown 8vo, cloth **2/0**

**MATERIALS AND CONSTRUCTION.** A Theoretical and Practical Treatise on the Strains, Designing, and Erection of Works of Construction. By F. CAMPIN. Crown 8vo, cloth . . . . . **3/0**

**MATERIALS, A TREATISE ON THE STRENGTH OF.** By P. Barlow, F.R.S., P. W. Barlow, F.R.S., and W. H. Barlow, F.R.S. Edited by Wm. Humber, A.M.Inst.C.E. 8vo, cloth . . . . **18/0**

"The standard treatise on that particular subject."—*Engineer.*

**MATHEMATICAL TABLES.** For Trigonometrical, Astronomical, and Nautical Calculations; to which is prefixed a Treatise on Logarithms, by H. Law, C.E. With Tables for Navigation and Nautical Astronomy. By Prof. J. R. Young. Crown 8vo, cloth . . . **4/0**

**MEASURES: BRITISH AND AMERICAN CUSTOMARY AND METRIC LEGAL MEASURES.** For Commercial and Technical Purposes, forming the Measure Section of Part I. of "The Mechanical Engineer's Reference Book." By Nelson Foley, M.I.N.A. Folio, cloth. *Net* **7/6**

Measures: Legal Standards—Lineal—Square—Cubic and Capacity—Weight—Compound Units—Velocity and Speed—Measures of Gravity—Mass—Force—Work—Power—Electrical—Heat—Moments—Energy—Momentum—Centrifugal Force—Angles—Equivalents: Customary Measures to Metric, and *vice versa*—Lineal—Square—Cubic and Capacity—Weights—Money (English, American, and French).

**MECHANICAL ENGINEERING.** Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Mechanical Manipulation, Manufacture of the Steam Engine, &c. By Francis Campin, C.E. Third Edition. Crown 8vo, cloth . . . . . **2/6**

**MECHANICAL ENGINEERING TERMS.** (Lockwood's Dictionary). Embracing terms current in the Drawing Office, Pattern Shop, Foundry, Fitting, Turning, Smiths', and Boiler Shops, &c. Comprising upwards of 6,000 Definitions. Edited by J. G. Horner, A.M.I.M.E. Third Edition, Revised, with Additions. Crown 8vo, cloth . . . *Net* **7/6**

**MECHANICAL ENGINEER'S COMPANION.** Areas, Circumferences, Decimal Equivalents, in inches and feet, millimetres, squares, cubes, roots, &c.; Strength of Bolts, Weight of Iron, &c.; Weights, Measures, and other Data. Also Practical Rules for Engine Proportions. By R. Edwards, M.Inst.C.E. F'cap. 8vo, cloth . . . . . **3/6**

**MECHANICAL ENGINEER'S POCKET-BOOK.** Comprising Tables, Formulæ, Rules, and Data: A Handy Book of Reference for Daily Use in Engineering Practice. By D. Kinnear Clark, M.Inst.C.E., Sixth Edition, thoroughly Revised and Enlarged. By H. H. P. Powles, A.M.Inst.C.E., M.I.M.E. Small 8vo, 700 pp., Leather . . *Net* **6/0**

Mathematical Tables—Measurement of Surfaces and Solids—English Weights and Measures—French Metric Weights and Measures—Foreign Weights and Measures—Moneys—Specific Gravity, Weight, and Volume—Manufactured Metals—Steel Pipes—Bolts and Nuts—Sundry Articles in Wrought and Cast Iron, Copper, Brass, Lead, Tin, Zinc—Strength of Materials—Strength of Timber—Strength of Cast Iron—Strength of Wrought Iron—Strength of Steel—Tensile Strength of Copper, Lead, &c.—Resistance of Stones and other Building Materials—Riveted Joints in Boiler Plates—Boiler Shells—Wire Ropes and Hemp Ropes—Chains and Chain Cables—Framing—Hardness of Metals, Alloys, and Stones—Labour of Animals—Mechanical Principles—Gravity and Fall of Bodies—Accelerating and Retarding Forces—Mill Gearing, Shafting, &c.—Transmission of Motive Power—Heat—Combustion: Fuels—Warming, Ventilation, Cooking Stoves—Steam—Steam Engines and Boilers—Railways—Tramways—Steam Ships—Pumping Steam Engines and Pumps—Coal Gas—Gas Engines, &c.—Air in Motion—Compressed Air—Hot Air Engines—Water Power—Speed of Cutting Tools—Colours—Electrical Engineering.

"It would be found difficult to compress more matter within a similar compass, or produce a book of 700 pages which should be more compact or convenient for pocket reference. . . . Will be appreciated by mechanical engineers of all classes."—*Practical Engineer.*

**MECHANICAL HANDLING OF MATERIAL.** A Treatise on the Handling of Material such as Coal, Ore, Timber, &c., by Automatic or Semi-Automatic Machinery, together with the Various Accessories used in the Manipulation of such Plant, and Dealing fully with the Handling, Storing, and Warehousing of Grain. By G. F. ZIMMER, A.M.Inst.C.E. 528 pages Royal 8vo, cloth, with 550 Illustrations (including Folding Plates) specially prepared for the Work . . . . *Net* **25/0**

"It is an essentially practical work written by a practical man, who is not only thoroughly acquainted with his subject theoretically, but who also has the knowledge that can only be obtained by actual experience in working and planning installations for the mechanical handling of raw material."—*The Times.*

**MECHANICS.** Being a concise Exposition of the General Principles of Mechanical Science and their Applications. By C. TOMLINSON, F.R.S. Crown 8vo, cloth . . . . . **1/6**

**MECHANICS: CONDENSED.** A Selection of Formulæ, Rules, Tables, and Data for the Use of Engineering Students, &c. By W. G. C. HUGHES, A.M.I.C.E. Crown 8vo, cloth . . . . . **2/6**

**MECHANICS OF AIR MACHINERY.** By Dr. J. WIESBACH and PROF. G. HERRMANN. Authorized Translation with an Appendix on American Practice by A. TROWBRIDGE, Ph.B., Adjunct Professor of Mechanical Engineering, Columbia University. Royal 8vo, cloth . . *Net* **18/0**

**MECHANICS' WORKSHOP COMPANION.** Comprising a great variety of the most useful Rules and Formulæ in Mechanical Science, with numerous Tables of Practical Data and Calculated Results for Facilitating Mechanical Operations. By WILLIAM TEMPLETON, Author of "The Engineer's Practical Assistant," &c., &c. Nineteenth Edition, Revised by W. S. HUTTON, C.E., Author of "The Works' Manager's Handbook," &c.; with an Electrical Section by A. P. HASLAM. F'cap. 8vo, nearly 500 pp., with 8 Plates and 275 Illustrations, leather . . . . . *Net* **5/0**

"This well-known and largely-used book contains information, brought up to date, of the sort so useful to the foreman and draughtsman. So much fresh information has been introduced as to constitute it practically a new book."—*Mechanical World.*

**MECHANISM AND MACHINE TOOLS.** By T. BAKER, C.E. With Remarks on Tools and Machinery by J. NASMYTH, C.E. Crown 8vo, cloth . . . . . **2/6**

**MENSURATION AND MEASURING.** With the Mensuration and Levelling of Land for the purposes of Modern Engineering. By T. BAKER, C.E. New Edition by E. NUGENT, C.E. Crown 8vo, cloth. **1/6**

**METAL-TURNING.** A Practical Handbook for Engineers, Technical Students, and Amateurs. By JOSEPH HORNER, A.M.I.Mech.E., Author of "Pattern Making," &c. Large crown 8vo, cloth, with 488 Illustrations . . . . . *Net* **9/0**

SUMMARY OF CONTENTS:—INTRODUCTION—RELATIONS OF TURNERY AND MACHINE SHOP—SEC. I. THE LATHE, ITS WORK, AND TOOLS—FORMS AND FUNCTIONS OF TOOLS—REMARKS ON TURNING IN GENERAL.—SEC. II. TURNING BETWEEN CENTRES—CENTRING AND DRIVING—USE OF STEADIES—EXAMPLES OF TURNING INVOLVING LINING-OUT FOR CENTRES—MANDREL WORK.—SEC. III. WORK SUPPORTED AT ONE END—FACE PLATE TURNING—ANGLE PLATE TURNING—INDEPENDENT JAW CHUCKS—CONCENTRIC, UNIVERSAL, TOGGLE, AND APPLIED CHUCKS.—SEC. IV. INTERNAL WORK—DRILLING, BORING, AND ALLIED OPERATIONS.—SEC. V. SCREW CUTTINGS AND TURRET WORK.—SEC. VI. MISCELLANEOUS — SPECIAL WORK — MEASUREMENT, GRINDING — TOOL HOLDERS—SPEED AND FEEDS, TOOL STEELS—STEEL MAKERS' INSTRUCTIONS.

**METRIC TABLES.** In which the British Standard Measures and Weights are compared with those of the Metric System at present in Use on the Continent. By C. H. DOWLING, C.E. 8vo, cloth . . . **10/6**

**MILLING MACHINES;** their Design, Construction, and Working. A Handbook for Practical Men and Engineering Students. By JOSEPH HORNER, A.M.I.Mech.E., Author of "Pattern Making," &c. With 269 Illustrations. Medium 8vo, cloth . . . . . *Net* **12/6**

LEADING ELEMENTS OF MILLING MACHINE DESIGN AND CONSTRUCTION—PLAIN AND UNIVERSAL MACHINES — ATTACHMENTS AND BRACINGS — VERTICAL SPINDLES MACHINES—PLANO-MILLERS OR SLABBING MACHINES—SPECIAL MACHINES—CUTTERS—MILLING OPERATIONS—INDEXING, SPIRAL WORK, AND WORM, SPUR, AND BEVEL GEARS &C.—SPUR AND BEVEL GEARS—FEED AND SPEEDS.

**MOTOR CAR, THE.** A Practical Manual for the use of Students and Motor Car Owners, with Notes on the Internal Combustion Engine and its Fuel. By ROBERT W. A. BREWER, A.M.Inst.C.E., M.I.M.E., M.I.A.E. 250 pp. With numerous Illustrations. Demy 8vo, cloth . . *Net* **5/0**

HISTORY OF THE INTERNAL COMBUSTION ENGINE—TWO-CYCLE ENGINES—LARGE ENGINES—SCAVENGING—MECHANICAL DETAILS OF CONSTRUCTION—DETAILS OF THE MOVING PARTS—STRATIFICATION—THERMAL EFFICIENCY—CAUSE AND EXTENT OF HEAT LOSSES—TESTING OF GAS ENGINES AND CALCULATIONS OF RESULTS—GAS PRODUCERS—OIL ENGINES—THE PETROL ENGINE AS EMPLOYED IN THE MOTOR CAR—POWER AND WEIGHT OF PETROL ENGINES—FRICTION AND LUBRICATION OF ENGINES—CLUTCHES AND CHANGE-SPEED GEARS—TRANSMISSION GEAR—LIVE AXLES AND CHAIN DRIVE—BRAKES—THE DIFFERENTIAL GEAR—FRAMES—SUSPENSION—STEERING—RADIATION—IGNITION MECHANISM—CARBURATION—LIQUID FUEL—BENZOL—FUEL MIXTURES—ALCOHOL—CARBURETTERS AND THE FLOW OF FUEL—MODERNISING A MOTOR CAR—THE CARE OF THE CAR.

"The book can be heartily commended to every one really interested in automobile engineering, and it will prove very useful to the practical owner of a car."—*The Car.*

**MOTOR CAR CATECHISM.** Containing about 320 Questions and Answers Explaining the Construction and Working of a Modern Motor Car. For the Use of Owners, Drivers, and Students. By JOHN HENRY KNIGHT. Second edition, revised and enlarged, with an additional chapter on Motor Cycles. Crown 8vo, with Illustrations. . . . . *Net* **1/6**

THE PETROL ENGINE—TRANSMISSION AND THE CHASSIS—TYRES—DUTIES OF A CAR DRIVER—MOTOR CYCLES—LAWS AND REGULATIONS.

**MOTOR CARS FOR COMMON ROADS.** By A. J. WALLIS-TAYLER, A.M.Inst.C.E. 212 pp., with 76 Illustrations. Crown 8vo, cloth . . . . . **4/6**

**MOTOR VEHICLES FOR BUSINESS PURPOSES.** A Practical Handbook for those interested in the Transport of Passengers and Goods. By A. J. WALLIS-TAYLER, A.M.Inst.C.E. With 134 Illustrations. Demy 8vo, cloth . . . . . *Net* **9/0**

**NAVAL ARCHITECT'S AND SHIPBUILDER'S POCKET BOOK.** Of Formulæ, Rules, and Tables, and Marine Engineer's and Surveyor's Handy Book of Reference. By CLEMENT MACKROW, M.I.N.A. Tenth Edition, F'cap, leather . . . . . *Net* **12/6**

SIGNS AND SYMBOLS, DECIMAL FRACTIONS—TRIGONOMETRY—PRACTICAL GEOMETRY—MENSURATION—CENTRES AND MOMENTS OF FIGURES—MOMENTS OF INERTIA AND RADII GYRATION—ALGEBRAICAL EXPRESSIONS FOR SIMPSON'S RULES—MECHANICAL PRINCIPLES—CENTRE OF GRAVITY—LAWS OF MOTION—DISPLACEMENT, CENTRE OF BUOYANCY—CENTRE OF GRAVITY OF SHIP'S HULL—STABILITY CURVES AND METACENTRES—SEA AND SHALLOW-WATER WAVES—ROLLING OF SHIPS—PROPULSION AND RESISTANCE OF VESSELS—SPEED TRIALS—SAILING, CENTRE OF EFFORT—DISTANCES DOWN RIVERS, COAST LINES—STEERING AND RUDDERS OF VESSELS—LAUNCHING CALCULATIONS AND VELOCITIES—WEIGHT OF MATERIAL AND GEAR—GUN PARTICULARS AND WEIGHT—STANDARD GAUGES—RIVETED JOINTS AND RIVETING—STRENGTH AND TESTS OF MATERIALS—BENDING AND SHEARING STRESSES—STRENGTH OF SHAFTING, PILLARS, WHEELS, &c.—HYDRAULIC DATA, &c.—CONIC SECTIONS, CATENARIAN CURVES—MECHANICAL POWERS, WORK—BOARD OF TRADE REGULATIONS FOR BOILERS AND ENGINES—BOARD OF TRADE REGULATIONS FOR SHIPS—LLOYD'S RULES FOR BOILERS—LLOYD'S WEIGHT OF CHAINS—LLOYD'S SCANTLINGS FOR SHIPS—DATA OF ENGINES AND VESSELS—SHIPS' FITTINGS AND TESTS—SEASONING PRESERVING TIMBER—MEASUREMENT OF TIMBER—ALLOYS, PAINTS, VARNISHES—DATA FOR STOWAGE—ADMIRALTY TRANSPORT REGULATIONS—RULES FOR HORSE-POWER, SCREW PROPELLERS, &c.—PERCENTAGES FOR BUTT STRAPS—PARTICULARS OF YACHTS—MASTING AND RIGGING—DISTANCES OF FOREIGN PORTS—TONNAGE TABLES—VOCABULARY OF FRENCH AND ENGLISH TERMS—ENGLISH WEIGHTS AND MEASURES—FOREIGN WEIGHTS AND MEASURES—DECIMAL EQUIVALENTS—USEFUL NUMBERS—CIRCULAR MEASURES—AREAS OF AND CIRCUMFERENCES OF CIRCLES—AREAS OF SEGMENTS OF CIRCLES—TABLES OF SQUARES AND CUBES AND ROOTS OF NUMBERS—TABLES OF LOGARITHMS OF NUMBERS—TABLES OF HYPERBOLIC LOGARITHMS—TABLES OF NATURAL SINES, TANGENTS—TABLES OF LOGARITHMIC SINES, TANGENTS, &c.

**NAVAL ARCHITECTURE.** An Exposition of the Elementary Principles. By J. PEAKE. Crown 8vo, cloth . . . . . **3/6**

**NAVIGATION AND NAUTICAL ASTRONOMY.** In Theory and Practice. By Prof. J. R. YOUNG. Crown 8vo, cloth . . . **2/6**

**NAVIGATION, PRACTICAL.** Consisting of the Sailor's Sea Book, by J. GREENWOOD and W. H. ROSSER; together with Mathematical and Nautical Tables for the Working of the Problems, by H. LAW, C.E., and Prof. J. R. YOUNG . . . . . **7/0**

**PATTERN MAKING.** Embracing the Main Types of Engineering Construction, and including Gearing, Engine Work, Sheaves and Pulleys, Pipes and Columns, Screws, Machine Parts, Pumps and Cocks, the Moulding of Patterns in Loam and Greensand, Weight of Castings, &c. By J. G. HORNER, A.M.I.M.E. Third Edition, Enlarged. With 486 Illustrations. Crown 8vo, cloth . . . . . *Net* **7/6**

**PATTERN MAKING.** A Practical Work on the Art of Making Patterns for Engineering and Foundry Work, including (among other matter, Materials and Tools, Wood Patterns, Metal Patterns, Pattern Shop Mathematics, Cost, Care, &c., of Patterns. By F. W. BARROWS. Fully Illustrated by Engravings made from Special Drawings by the Author. Crown 8vo, cloth. *Net* **6/0**

PATTERN MAKERS AND PATTERN MAKING—MATERIALS AND TOOLS—EXAMPLES OF PATTERN WORK—METAL PATTERNS—PATTERN SHOP MATHEMATICS—COST, CARE, AND INVENTORY OF PATTERNS—MARKING AND RECORD OF PATTERNS—PATTERN ACCOUNTS.

**PETROL AIR GAS.** A Practical Hand-book on the Installation and Working of Air Gas Lighting Systems for Country Houses. By HENRY O'CONNOR, F.R.S.E., A.M.Inst.C.E., &c., Author of "The Gas Engineer's Pocket-Book." 80 Pages with Illustrations. Crown 8vo, cloth. *Net* **1/6**

**PETROLEUM MINING AND OIL-FIELD DEVELOPMENT.** A Guide to the Exploration of Petroleum Lands, and a Study of the Engineering Problems connected with the Winning of Petroleum, including Statistical Data of Important Oil-fields, Notes on the Origin and Distribution of Petroleum, and a Description of the Methods of Utilising Oil and Gas Fuel. By A. BEEBY THOMPSON, A.M.I.Mech.E., F.G.S., Author of "The Oil-fields of Russia." 384 pages, 114 Illustrations, including 22 full-page Plates. Demy 8vo, cloth . . . . . [*Just Published. Net* **15/0**

"It is an admirable text-book by a competent authority on an interesting subject."—*Mining Magazine.*

"The present effort is likely to receive a warm welcome in engineering circles, and it can be cordially commended for perusal. It will doubtless have that large sale to which its merits entitle it."—*Mining World.*

"The general aspects of the Petroleum Industry are fully and ably laid out."—*Engineer.*

**PIONEER ENGINEERING.** A Treatise on the Engineering Operations connected with the Settlement of Waste Lands in New Countries. By E. DOBSON, M.Inst.C.E. Second Edition. Crown 8vo, cloth . . . . . **4/6**

**PNEUMATICS.** Including Acoustics and the Phenomena of Wind Currents, for the use of Beginners. By CHARLES TOMLINSON, F.R.S. Crown 8vo, cloth . . . . . **1/6**

**PORTLAND CEMENT, THE MODERN MANUFACTURE OF.** A Handbook for Manufacturers, Users, and all interested in Portland Cement. By PERCY C. H. WEST, Fellow of the Chemical Society and of the Society of Chemical Industry. Vol. I.—Machinery and Kilns. 280 pages, with 159 Illustrations and numerous Tables. Royal 8vo, cloth.

[*Just Published. Net* **12/6**

WASH-MILLS—WET EDGE-RUNNERS AND STONE-MILLS—WET TUBE-MILLS—OTHER WET MILLS AND ACCESSORY PLANT—WET PROCESS—CRUSHERS DRIERS—MILLSTONES, EDGE-RUNNERS, DISINTEGRATORS, &c.—BALL-MILLS—CENTRIFUGAL ROLL-MILLS—TUBE-MILLS CONVEYORS AND ELEVATORS—DUST COLLECTORS—WEIGHING MACHINES SEPARATORS AND AUTOMATIC FEEDERS — PRESSING AND DRYING BRIQUETTES—SHAFT AND OTHER STATIONARY KILNS—ROTARY KILNS—COAL DRYING AND GRINDING—STORING AND GRINDING THE CLINKER—WAREHOUSING AND PACKING THE CEMENT—DESCRIPTIONS OF SOME MODERN CEMENT PLANTS.

**PRODUCER GAS PRACTICE (AMERICAN) AND INDUSTRIAL GAS ENGINEERING.** By NISBET LATTA, M.Amer.Soc. M.E., M.Amer. Gas Inst. 558 pages, with 247 Illustrations. Demy 4to, cloth . . . . . [*Just published. Net* **25/0**

PRODUCER OPERATION—CLEANING THE GAS—WORKS DETAILS—PRODUCER TYPES—MOVING GASES—SOLID FUELS—PHYSICAL PROPERTIES OF GASES—CHEMICAL PROPERTIES OF GASES—GAS ANALYSIS—GAS POWER—GAS ENGINES—INDUSTRIAL GAS APPLICATIONS—FURNACES AND KILNS—BURNING LIME AND CEMENT—PRE-HEATING AIR—DOHERTY COMBUSTION ECONOMIZER—COMBUSTION IN FURNACES—HEAT TEMPERATURE, RADIATION AND CONDUCTION—HEAT MEASUREMENTS: PYROMETRY AND CALORIMETRY—PIPES, FLUES AND CHIMNEYS—MATERIALS: FIRECLAY, MASONRY, WEIGHTS AND ROPE—USEFUL TABLES—OIL FUEL PRODUCER GAS.

**PRODUCER GAS.** See also GAS ENGINES AND PRODUCER GAS PLANTS.

**PUMPS AND PUMPING.** A Handbook for Pump Users. Being Notes on Selection, Construction, and Management. By M. POWIS BALE, M.Inst.C.E., M.I.Mech.E. Fifth Edition. Crown 8vo, cloth . **3/6**

**PUNCHES, DIES, AND TOOLS FOR MANUFACTURING IN PRESSES.** By JOSEPH V. WOODWORTH. Medium 8vo, cloth. 482 pages, with 700 Illustrations . . . . . *Net* **16/0**

SIMPLE BENDING AND FORMING DIES, THEIR CONSTRUCTION, USE AND OPERATION—INTRICATE COMBINATION, BENDING AND FORMING DIES, FOR ACCURATE AND RAPID PRODUCTION—AUTOMATIC FORMING, BENDING AND TWISTING DIES AND PUNCHES, FOR DIFFICULT AND NOVEL SHAPING—CUT, CARRY, AND FOLLOW DIES, TOGETHER WITH TOOL COMBINATIONS FOR PROGRESSIVE SHEET METAL WORKING—NOTCHING PERFORATING AND PIERCING PUNCHES, DIES AND TOOLS—COMPOSITE, SECTIONAL, COMPOUND AND ARMATURE DISK AND SEGMENT PUNCHES AND DIES—PROCESSES AND TOOLS FOR MAKING RIFLE CARTRIDGES, CARTRIDGE CASES OF QUICK-FIRING GUNS, AND NICKEL BULLET JACKETS—THE MANUFACTURE AND USE OF DIES FOR DRAWING WIRE AND BAR STEEL—PENS, PINS, AND NEEDLES, THEIR EVOLUTION AND MANUFACTURE—PUNCHES, DIES, AND PROCESSES FOR MAKING HYDRAULIC PACKING LEATHERS, TOGETHER WITH TOOLS FOR PAINT AND CHEMICAL TABLETS—DRAWING, RE-DRAWING, REDUCING, FLANGING, FORMING, REVERSING, AND CUPPING PROCESSES, PUNCHES AND DIES FOR CIRCULAR AND RECTANGULAR AND SHEET-METAL ARTICLES—BEADING, WIRING, CURLING AND SEAMING PUNCHES AND DIES FOR CLOSING AND ASSEMBLING OF METAL PARTS—JEWELLERY DIE-MAKING, EYE GLASS, LENS AND MEDAL DIES, AND CONSTRUCTION OF SPOON AND FORK-MAKING TOOLS—DESIGN, CONSTRUCTION AND USE OF SUB-PRESSES AND SUB-PRESS DIES FOR WATCH AND CLOCK WORK AND ACCURATE PIERCING AND PUNCHING—DROP FORGING AND DIE SINKING, TOGETHER WITH MAKING OF DROP DIES, STEAM-HAMMER DIES, NUMBER-PLATE TOOLS AND DIES FOR BOLT MACHINES—METHODS, DESIGNS, WAYS, KINKS, FORMULAS AND TOOLS FOR SPECIAL WORK, TOGETHER WITH MISCELLANEOUS INFORMATION OF VALUE TO TOOL AND DIE MAKERS AND SHEET-METAL GOODS MANUFACTURERS—SPECIAL AND NOVEL PROCESSES, PRESSES AND FEEDS FOR WORKING SHEET METAL IN DIES.

**RECLAMATION OF LAND FROM TIDAL WATERS.** A Handbook for Engineers, Landed Proprietors, and others interested in Works of Reclamation. By A. BEAZELEY, M.Inst.C.E. 8vo, cloth. *Net* **10/6**

"The work contains a great deal of practical and useful information which cannot fail to be of service to engineers entrusted with the enclosure of salt marshes, and to land-owners intending to reclaim land from the sea."—*The Engineer.*

**RECOIL OF GUNS WITH RECOIL CYLINDERS, THE THEORY OF.** By Professor F. RAUSENBERGER. Specially printed from "Artilleristische Monatshefte." Translated by ALFRED SLATER. 100 pages, with 3 Plates. Demy 8vo, cloth . . . . . *Net* **10/6**

THE EXTERNAL FORCES ON A RECOILING GUN-MOUNTING WHICH COME INTO ACTION ON FIRING—DETERMINATION OF THE BRAKE PRESSURE AND THE LENGTH OF RECOIL—THE RUNNING-FORWARD DEVICE—RECOIL BRAKES—THE RUNNING-FORWARD BRAKE—NOTATION USED.

**REFRIGERATION AND ICE-MAKING POCKET BOOK.** By A. J. WALLIS-TAYLER, A.M.Inst.C.E. Author of "Refrigerating and Ice-making Machinery," &c. Fourth Edition. Crown 8vo, cloth. *Net* **3/6**

**REFRIGERATION, COLD STORAGE, & ICE-MAKING:** A Practical Treatise on the Art and Science of Refrigeration. By A. J. WALLIS-TAYLER, A.M.Inst.C.E. Containing the Third Edition of "Refrigerating and Ice-Making Machinery." Second Edition. 600 pp., with 360 Illustrations. Medium 8vo, cloth. . . [*Just Published. Net* **10/6**

"The author has to be congratulated on the completion and production of such an important work and it cannot fail to have a large body of readers, for it leaves out nothing that would in any way be of value to those interested in the subject."—*Steamship.*

**RIVER BARS.** The Causes of their Formation, and their Treatment by "Induced Tidal Scour"; with a Description of the Successful Reduction by this Method of the Bar at Dublin. By I. J. MANN, Assist. Eng. to the Dublin Port and Docks Board. Royal 8vo, cloth . . **7/6**

"We recommend all interested in harbour works—and, indeed, those concerned in the improvement of rivers generally—to read Mr. Mann's interesting work."—*Engineer.*

**ROADS AND STREETS.** By H. LAW, C.E., and D. K. CLARK, C.E. Revised, with Additional Chapters by A. J. WALLIS-TAYLER, A.M.Inst.C.E. Seventh Edition. Crown 8vo, cloth . . . . **6/0**

"A book which every borough surveyor and engineer must possess, and which will be of considerable service to architects, builders, and property owners generally."—*Building News.*

**ROOFS OF WOOD AND IRON.** Deduced chiefly from the Works of Robison, Tredgold, and Humber. By E. W. TARN, M.A., Architect. Fifth Edition. Crown 8vo, cloth . . . . . **1/6**

**SAFE RAILWAY WORKING.** A Treatise on Railway Accidents, their Cause and Prevention; with a Description of Modern Appliances and Systems. By CLEMENT E. STRETTON, C.E. Third Edition, Enlarged. Crown 8vo, cloth . . . . . **3/6**

**SAFE USE OF STEAM.** Containing Rules for Unprofessional Steam Users. By an ENGINEER. Eighth Edition. Sewed . **6d.**

"If steam-users would but learn this little book by heart, boiler explosions would become sensations by their rarity."—*English Mechanic.*

**SAILMAKING.** By SAMUEL B. SADLER, Practical Sailmaker, late in the employment of Messrs. Ratsey and Lapthorne, of Cowes and Gosport. Second Edition. Revised and Enlarged. Plates. 4to, cloth *Net* **12/6**

**SAILOR'S SEA BOOK.** A Rudimentary Treatise on Navigation. By JAMES GREENWOOD, B.A. With numerous Woodcuts and Coloured Plates. New and Enlarged Edition. By W. H. ROSSER. Crown 8vo, cloth . . . . . **2/6**

**SAILS AND SAIL-MAKING.** With Draughting, and the Centre of Effort of the Sails. Weights and Sizes of Ropes; Masting, Rigging, and Sails of Steam Vessels, &c. By R. KIPPING, N.A. Crown 8vo, cloth . . . . . **2/6**

**SCREW-THREADS,** and Methods of Producing Them. With numerous Tables and complete Directions for using Screw-Cutting Lathes. By PAUL N. HASLUCK, Author of "Lathe-Work," &c. Sixth Edition. Waistcoat-pocket size . . . . . **1/6**

"Full of useful information, hints and practical criticism. Taps, dies, and screwing tools generally are illustrated and their action described."—*Mechanical World.*

**SEA TERMS, PHRASES, AND WORDS;** Technical Dictionary (French-English, English-French), used in the English and French Languages. For the Use of Seamen, Engineers, Pilots, Shipbuilders, Shipowners, and Shipbrokers. Compiled by W. PIRRIE, late of the African Steamship Company. F'cap. 8vo, cloth . . . . . **5/0**

**SHIPBUILDING INDUSTRY OF GERMANY.** Compiled and Edited by G. LEHMANN-FELSKOWSKI. With Coloured Prints, Art Supplements, and numerous Illustrations throughout the text. Super-royal 4to, cloth . . . . . *Net* **10/6**

**SHIPS AND BOATS.** By W. BLAND. With numerous Illustrations and Models. Tenth Edition. Crown 8vo, cloth . . **1/6**

**SHIPS FOR OCEAN AND RIVER SERVICE.** Principles of the Construction of. By H. A. SOMMERFELDT. Crown 8vo . . **1/6**

ATLAS OF ENGRAVINGS to illustrate the above. Twelve large folding Plates. Royal 4to, cloth . . . . . **7/6**

**SMITHY AND FORGE.** Including the Farrier's Art and Coach Smithing. By W. J. E. CRANE. Crown 8vo, cloth . . **2/6**

**STATICS, GRAPHIC AND ANALYTIC.** In their Practical Application to the Treatment of Stresses in Roofs, Solid Girders, Lattice, Bowstring, and Suspension Bridges, Braced Iron Arches and Piers, and other Frameworks. By R. HUDSON GRAHAM, C.E. Containing Diagrams and Plates to Scale. With numerous Examples, many taken from existing Structures. Specially arranged for Class-work in Colleges and Universities. Second Edition, Revised and Enlarged. 8vo, cloth . . . . **16/0**

"Mr. Graham's book will find a place wherever graphic and analytic statics are used or tudied."—*Engineer.*

**STATIONARY ENGINE DRIVING.** A Practical Manual for Engineers in Charge of Stationary Engines. By MICHAEL REYNOLDS, M.S.E. Eighth Edition. Crown 8vo, cloth, **3/6**; cloth boards . **4/6**

"The author is thoroughly acquainted with his subjects, and has produced a manual which is an exceedingly useful one for the class for whom it is specially intended."—*Engineering.*

**STATIONARY ENGINES.** A Practical Handbook of their Care and Management for Men-in-charge. By C. HURST. Crown 8vo. *Net* **1/0**

**STEAM: THE APPLICATION OF HIGHLY SUPER-HEATED STEAM TO LOCOMOTIVES.** Being a reprint from a Series of Articles appearing in the *Engineer.* By ROBERT GARBE, Privy Councillor, Prussian State Railways. Translated from the German. Edited by LESLIE S. ROBERTSON, Secretary of the Engineering Standards Committee, M.Inst.C.E., M.I.Mech.E., M.Inst.N.A., &c. Medium 8vo, cloth **7/6**

**STEAM AND THE STEAM ENGINE.** Stationary and Portable. Being an Extension of the Treatise on the Steam Engine of Mr. J. SEWELL. By D. K. CLARK, C.E. Fourth Edition. Crown 8vo, cloth . . . . . **3/6**

"Every essential part of the subject is treated of competently, and in a popular style."—*Iron.*

**STEAM AND MACHINERY MANAGEMENT.** A Guide to the Arrangement and Economical Management of Machinery, with Hints on Construction and Selection. By M. POWIS BALE, M.Inst.M.E. Crown 8vo, cloth . . . . . **2/6**

"Gives the results of wide experience."—*Lloyd's Newspaper.*

**STEAM ENGINE.** A Practical Handbook compiled with especial Reference to Small and Medium-sized Engines. For the Use of Engine Makers, Mechanical Draughtsmen, Engineering Students, and users of Steam Power. By HERMAN HAEDER, C.E. Translated from the German with additions and alterations, by H. H. P. POWLES, A.M.I.C.E., M.I.M.E. Third Edition, Revised. With nearly 1,100 Illustrations. Crown 8vo, cloth . . . . . *Net* **7/6**

"This is an excellent book, and should be in the hands of all who are interested in the construction and design of medium-sized stationary engines. . . . A careful study of its contents and the arrangement of the sections leads to the conclusion that there is probably no other book like it in this country. The volume aims at showing the results of practical experience, and it certainly may claim a complete achievement of this idea."—*Nature.*

**STEAM ENGINE.** A Treatise on the Mathematical Theory of, with Rules and Examples for Practical Men. By T. BAKER, C.E. Crown 8vo, cloth . . . . . **1/6**

"Teems with scientific information with reference to the steam-engine."—*Design and Work.*

**STEAM ENGINE.** A Text-Book on the Steam Engine, with a Supplement on GAS ENGINES and PART II. on HEAT ENGINES. By T. M. GOODEVE, M.A., Barrister-at-Law, Professor of Mechanics at the Royal College of Science, London; Author of "The Principles of Mechanics," "The Elements of Mechanism," &c. Fourteenth Edition. Crown 8vo, cloth . **6/0**

"Professor Goodeve has given us a treatise on the steam engine, which will bear comparison with anything written by Huxley or Maxwell, and we can award it no higher praise."—*Engineer.*

"Mr. Goodeve's text-book is a work of which every young engineer should possess himself."—*Mining Journal.*

**STEAM ENGINE.** For the Use of Beginners. By Dr. LARDNER. Crown 8vo, cloth . . . . . **1/6**

**STEAM ENGINE (PORTABLE).** A Practical Manual on its Construction and Management. For the use of Owners and Users of Steam Engines generally. By WILLIAM DYSON WANSBROUGH. Crown 8vo, cloth . . . . . **3/6**

"This is a work of value to those who use steam machinery. . . . Should be read by every one who has a steam engine, on a farm or elsewhere."—*Mark Lane Express.*

**STEAM ENGINEERING IN THEORY AND PRACTICE.** By GARDNER D. HISCOX, M.E. With Chapters on Electrical Engineering. By NEWTON HARRISON, E.E., Author of "Electric Wiring, Diagrams, and Switchboards." 450 pages. Over 400 Detailed Engravings. *Net* **12/6**

HISTORICAL—STEAM AND ITS PROPERTIES—APPLIANCES FOR THE GENERATION OF STEAM—TYPES OF BOILERS—CHIMNEY AND ITS WORK—HEAT ECONOMY OF THE FEED WATER—STEAM PUMPS AND THEIR WORK—INCRUSTATION AND ITS WORK—STEAM ABOVE ATMOSPHERIC PRESSURE—FLOW OF STEAM FROM NOZZLES—SUPERHEATED STEAM AND ITS WORK—ADIABATIC EXPANSION OF STEAM—INDICATOR AND ITS WORK—STEAM ENGINE PROPORTIONS—SLIDE VALVE ENGINES AND VALVE MOTION—CORLISS ENGINE AND ITS VALVE GEAR—COMPOUND ENGINE AND ITS THEORY—TRIPLE AND MULTIPLE EXPANSION ENGINE—STEAM TURBINE—REFRIGERATION—ELEVATORS AND THEIR MANAGEMENT—COST OF POWER—STEAM ENGINE TROUBLES—ELECTRIC POWER AND ELECTRIC PLANTS.

**STEAM TURBINES.** See MARINE STEAM TURBINE.

**STONE BLASTING AND QUARRYING.** For Building and other Purposes. With Remarks on the Blowing up of Bridges. By Gen. Sir J. BURGOYNE, K.C.B. Crown 8vo, cloth . . . . . **1/6**

**STONE-WORKING MACHINERY.** A Manual dealing with the Rapid and Economical Conversion of Stone. With Hints on the Arrangement and Management of Stone Works. By M. POWIS BALE, M.Inst.C.E. Crown 8vo, cloth . . . . . **9/0**

"Should be in the hands of every mason or student of stonework."—*Colliery Guardian.*

**STRAINS, HANDY BOOK FOR THE CALCULATION OF.** In Girders and Similar Structures and their Strength. Consisting of Formulæ and Corresponding Diagrams, with numerous details for Practical Application, &c. By WILLIAM HUMBER, A. M.Inst.C.E., &c. Sixth Edition. Crown 8vo, with nearly 100 Woodcuts and 3 Plates, cloth . . . **7/6**

"We heartily commend this really *handy* book to our engineer and architect readers."—*English Mechanic.*

**STRAINS ON STRUCTURES OF IRONWORK.** With Practical Remarks on Iron Construction. By F. W. SHEILDS, M.Inst.C.E. 8vo, cloth . . . . . **5/0**

**SUBMARINE TELEGRAPHS.** Their History, Construction, and Working. Founded in part on WÜNSCHENDORFF'S "Traité de Télégraphie Sous-Marine," and Compiled from Authoritative and Exclusive Sources. By CHARLES BRIGHT, F.R.S.E., A.M.Inst.C.E., M.I.Mech.E., M.I.E.E. Super royal 8vo, nearly 800 pages, fully Illustrated, including a large number of Maps and Folding Plates, strongly bound in cloth *Net* **£3 3s.**

"Mr. Bright's interestingly written and admirably illustrated book will meet with a welcome reception from cable men."—*Electrician.*

**SUPERHEATED STEAM, THE APPLICATION OF, TO LOCOMOTIVES.** See STEAM.

**SURVEYING AS PRACTISED BY CIVIL ENGINEERS AND SURVEYORS.** Including the Setting-ont of Works for Construction and Surveys Abroad, with many Examples taken from Actual Practice. A Handbook for use in the Field and the Office, intended also as a Text-book for Students. By JOHN WHITELAW, Jun., A.M.Inst.C.E., Author of "Points and Crossings." With about 260 Illustrations. Second Edition. Demy 8vo, cloth . . . . . *Net* **10/6**

SURVEYING WITH THE CHAIN ONLY—SURVEYING WITH THE AID OF ANGULAR INSTRUMENTS—LEVELLING—ADJUSTMENT OF INSTRUMENTS—RAILWAY (INCLUDING ROAD) SURVEYS AND SETTING OUT—TACHEOMETRY OR STADIA SURVEYING—TUNNEL ALIGNMENT AND SETTING OUT—SURVEYS FOR WATER SUPPLY WORKS—HYDROGRAPHICAL OR MARINE SURVEYING—ASTRONOMICAL OBSERVATIONS USED IN SURVEYING—EXPLANATIONS OF ASTRONOMICAL TERMS—SURVEYS ABROAD IN JUNGLE, DENSE FOREST, AND UNMAPPED OPEN COUNTRY—TRIGONOMETRICAL OR GEODETIC SURVEYS.

"This work is written with admirable lucidity, and will certainly be found of distinct value both to students and to those engaged in actual practice."—*The Builder.*

**SURVEYING, LAND AND ENGINEERING.** For Students and Practical Use. By T. BAKER, C.E. Twentieth Edition, by F. E. DIXON, A.M.Inst.C.E. With Plates and Diagrams. Crown 8vo, cloth **2/0**

**SURVEYING, LAND AND MARINE.** In Reference to the Preparation of Plans for Roads and Railways; Canals, Rivers, Towns, Water Supplies; Docks and Harbours. With Description and Use of Surveying Instruments. By W. DAVIS HASKOLL, C.E. Second Edition, Revised with Additions. Large crown 8vo, cloth . . . . . **9/0**

"This book must prove of great value to the student. We have no hesitation in recommending it, feeling assured that it will more than repay a careful study."—*Mechanical World.*

**SURVEYING, PRACTICAL.** A Text-book for Students Preparing for Examinations or for Survey Work in the Colonies. By GEORGE W. USILL, A.M.Inst.C.E. Eighth Edition, thoroughly Revised and Enlarged by ALEX. BEAZELEY, M.Inst.C.E. With 4 Lithographic Plates and 360 Illustrations. Large crown 8vo, **7/6** cloth; or, on thin paper, leather, gilt edges, rounded corners, for pocket use . . . . . **12/6**

ORDINARY SURVEYING—SURVEYING INSTRUMENTS—TRIGONOMETRY REQUIRED IN SURVEYING—CHAIN SURVEYING—THEODOLITE SURVEYING—TRAVERSING—TOWN-SURVEYING—LEVELLING—CONTOURING—SETTING OUT CURVES—OFFICE WORK—LAND QUANTITIES—COLONIAL LICENSING REGULATIONS—HYPSOMETER TABLES—INTRODUCTION TO TABLES OF NATURAL SINES, &C.—NATURAL SINES AND CO-SINES—NATURAL TANGENTS AND CO-TANGENTS—NATURAL SECANTS AND CO-SECANTS.

"The first book which should be put in the hands of a pupil of civil engineering."—*Architect.*

**SURVEYING TRIGONOMETRICAL.** An outline of the Method of Conducting a Trigonometrical Survey. For the Formation of Geographical and Topographical Maps and Plans, Military Reconnaissance, Levelling, &c., with Useful Problems, Formulæ, and Tables. By Lieut.-General FROME, R.E. Fourth Edition, Revised and partly Re-written by Major-General Sir CHARLES WARREN, G.C.M.G., R.E. With 19 Plates and 115 Woodcuts, royal 8vo, cloth . . . . . **16/0**

**SURVEYING WITH THE TACHEOMETER.** A Practical Manual for the use of Civil and Military Engineers and Surveyors, including two series of Tables specially computed for the Reduction of Readings in Sexagesimal and in Centesimal Degrees. By NEIL KENNEDY, M.Inst.C.E., With Diagrams and Plates. Second Edition. Demy 8vo, cloth *Net* **10/6**

"The work is very clearly written, and should remove all difficulties in the way of any surveyor desirous of making use of this useful and rapid instrument."—*Nature.*

**SURVEY PRACTICE.** For Reference in Surveying, Levelling, and Setting-out; and in Route Surveys of Travellers by Land and Sea. With Tables, Illustrations, and Records. By L. D'A. JACKSON, A.M.Inst.C.E. Second Edition. 8vo, cloth . . . . . **12/6**

**SURVEYOR'S FIELD BOOK FOR ENGINEERS AND MINING SURVEYORS.** Consisting of a Series of Tables, with Rules, Explanations of Systems, and use of Theodolite for Traverse Surveying and plotting the work with minute accuracy by means of Straight Edge and Set Square only; Levelling with the Theodolite, Setting-out Curves with and without the Theodolite, Earthwork Tables, &c. By W. DAVIS HASKOLL, C.E. With numerous Woodcuts. Fifth Edition, Enlarged. Crown 8vo, cloth . . . . . **12/0**

**TECHNICAL TERMS, ENGLISH-FRENCH, FRENCH-ENGLISH:** A Pocket Glossary; with Tables suitable for the Architectural Engineering, Manufacturing, and Nautical Professions. By JOHN JAMES FLETCHER. Fourth Edition, 200 pp. Waistcoat-pocket size, limp leather . . . . . **1/6**

**TECHNICAL TERMS, ENGLISH-GERMAN, GERMAN-ENGLISH.** A Pocket Glossary suitable for the Engineering, Manufacturing, and Mining Industries. Compiled by J. G. HORNER, A.M.I.Mech.E., in collaboration with ALFRED SCHLOMANN, Editor of "Illustrated Technical Dictionaries in Six Languages." Waistcoat-pocket size.

[*In preparation. Price about* **2/6** *net.*

**TECHNICAL TERMS, ENGLISH-SPANISH, SPANISH-ENGLISH:** A Pocket Glossary suitable for the Engineering, Manufacturing and Mining Industries. By R. D. MONTEVERDE, B.A. (Madrid). 316 pp. Waistcoat-pocket size, limp leather . . . . . *Net* **2/6**

**TELEPHONES: THEIR CONSTRUCTION, INSTALLATION, WIRING, OPERATION AND MAINTENANCE.** A Practical Reference Book and Guide for Electricians, Wiremen, Engineers, Contractors, Architects, and others interested in Standard Telephone Practice. By W. H. RADCLIFFE and H. C. CUSHING, JR. 180 pages. With 125 Illustrations. F'cap 8vo, cloth . . . . . *Net* **4/6**

**TELEPHONES: FIELD TELEPHONES FOR ARMY USE: INCLUDING AN ELEMENTARY COURSE IN ELECTRICITY AND MAGNETISM.** By Lieut. E. J. STEVENS, D.O., R.A., A.M.I.E.E., Instructor in Electricity, Ordnance College, Woolwich. Crown 8vo, cloth. With Illustrations . . . . . *Net* **2/0**

BATTERIES—ELECTRICAL CIRCUITS—MAGNETISM—INDUCTION—MICROPHONES AND RECEIVERS—PORTABLE AND FIELD TELEPHONE SETS—SELF-INDUCTION, INDUCTIVE CAPACITY, &C.

**TELEPHONY.** See WIRELESS TELEPHONY and WIRELESS TELEGRAPHY.

**THREE-PHASE TRANSMISSION.** See ELECTRICAL TRANSMISSION OF ENERGY.

**TOOLS FOR ENGINEERS AND WOODWORKERS.** Including Modern Instruments of Measurement. By JOSEPH HORNER, A.M.Inst.M.E., Author of "Pattern Making," &c. Demy 8vo, with 456 Illustrations . . . . . *Net* **9/0**

GENERAL SURVEY OF TOOLS—TOOL ANGLES. CHISEL GROUP—CHISELS AND APPLIED FORMS FOR WOODWORKERS—PLANES—HAND CHISELS AND APPLIED FORMS FOR METAL WORKING—CHISEL-LIKE TOOLS FOR METAL TURNING, PLANING, &c.—SHEARING ACTION AND SHEARING TOOLS. EXAMPLES OF SCRAPING TOOLS. TOOLS—RELATING TO CHISELS AND SCRAPES—SAWS—FILES—MILLING CUTTERS—BORING TOOLS FOR WOOD AND METAL—TAPS AND DIES. PERCUSSIVE AND MOULDING TOOLS—PUNCHES, HAMMERS AND CAULKING TOOLS—MOULDING AND MODELLING TOOLS—MISCELLANEOUS TOOLS, &c.

**TOOTHED GEARING.** A Practical Handbook for Offices and Workshops. By J. HORNER, A.M.I.M.E. Second Edition, with a New Chapter on Recent Practice. With 184 Illustrations. Crown 8vo, cloth **6/0**

**TRAMWAYS: THEIR CONSTRUCTION AND WORKING.** Embracing a Comprehensive History of the System; with an exhaustive Analysis of the Various Modes of Traction, including Horse Power, Steam Cable Traction, Electric Traction, &c.; a Description of the Varieties of Rolling Stock; and ample Details of Cost and Working Expenses. New Edition, Thoroughly Revised, and Including the Progress recently made in Tramway Construction, &c. By D. KINNEAR CLARK, M.Inst.C.E. With 400 Illustrations. 8vo, 780 pp., buckram . . . . . **28/0**

**TRUSSES OF WOOD AND IRON.** Practical Applications of Science in Determining the Stresses, Breaking Weights, Safe Loads, Scantlings, and Details of Construction. With Complete Working Drawings. By W. GRIFFITHS, Surveyor. Oblong 8vo, cloth . . . . . **4/6**

"This handy little book enters so minutely into every detail connected with the construction of roof trusses that no student need be ignorant of these matters."—*Practical Engineer.*

**TUNNELLING.** A Practical Treatise. By CHARLES PRELINI, C.E. With additions by CHARLES S. HILL, C.E. With 150 Diagrams and Illustrations. Royal 8vo, cloth . . . . . *Net* **16/0**

**TUNNELLING, PRACTICAL.** Explaining in detail the Setting-out the Works, Shaft-sinking, and Heading-driving, Ranging the Lines and Levelling underground, Sub-Excavating, Timbering and the Construction of the Brickwork of Tunnels. By F. W. SIMMS, M.Inst.C.E. Fourth Edition, Revised and Further Extended, including the most recent (1895) Examples of Sub-aqueous and other Tunnels, by D. KINNEAR CLARK, M.Inst.C.E. With 34 Folding Plates. Imperial 8vo, cloth . . . . . **£2 2s.**

**TUNNEL SHAFTS.** A Practical and Theoretical Essay on the construction of large Tunnel Shafts. By J. H. WATSON BUCK, M.Inst.C.E., Resident Engineer, L. and N. W. R. With Folding Plates, 8vo, cloth **12/0**

"Will be regarded by civil engineers as of the utmost value and calculated to save much time and obviate many mistakes."—*Colliery Guardian.*

**WAGES TABLES.** At 54, 52, 50, and 48 Hours per Week. Showing the Amounts of Wages from One quarter of an hour to Sixty-four hours, in each case at Rates of Wages advancing by One Shilling from 4s. to 55s. per week. By THOS. GARBUTT, Accountant. Square crown 8vo, half-bound . . . . . **6/0**

**WATER ENGINEERING.** A Practical Treatise on the Measurement, Storage, Conveyance, and Utilization of Water for the Supply of Towns, for Mill Power, and for other Purposes. By CHARLES SLAGG, A.M.Inst.C.E. Second Edition. Crown 8vo, cloth . . . . . **7/6**

**WATER, FLOW OF.** A New Theory of the Motion of Water under Pressure and in Open Conduits and its Practical Application. By LOUIS SCHMEER, Civil and Irrigation Engineer. 234 pages, with Illustrations. Medium 8vo, cloth . . . . [*Just published. Net* **12/6**

**WATER, POWER OF.** As Applied to Drive Flour Mills and to give motion to Turbines and other Hydrostatic Engines. By JOSEPH GLYNN, F.R.S., &c. New Edition. Illustrated. Crown 8vo, cloth **2/0**

**WATER SUPPLY OF CITIES AND TOWNS.** By WILLIAM HUMBER, A.M.Inst.C.E., and M.Inst.M.E., Anthor of "Cast and Wrought Iron Bridge Construction," &c., &c. Illustrated with 50 Double Plates, 1 Single Plate, Coloured Frontispiece, and upwards of 250 Woodcuts, and containing 400 pp. of Text. Imp. 4to, elegantly and substantially half-bound in morocco . . . . . *Net* **£6 6s.**

LIST OF CONTENTS:—I. HISTORICAL SKETCH OF SOME OF THE MEANS THAT HAVE BEEN ADOPTED FOR THE SUPPLY OF WATER TO CITIES AND TOWNS.—II. WATER AND THE FOREIGN MATTER USUALLY ASSOCIATED WITH IT.—III. RAINFALL AND EVAPORATION.—IV. SPRINGS AND THE WATER-BEARING FORMATIONS OF VARIOUS DISTRICTS.—V. MEASUREMENT AND ESTIMATION OF THE FLOW OF WATER.—VI. ON THE SELECTION OF THE SOURCE OF SUPPLY.—VII. WELLS.—VIII. RESERVOIRS.—IX. THE PURIFICATION OF WATER.—X. PUMPS.—XI. PUMPING MACHINERY.—XII. CONDUITS.—XIII. DISTRIBUTION OF WATER.—XIV. METERS, SERVICE PIPES, AND HOUSE FITTINGS.—XV. THE LAW AND ECONOMY OF WATER-WORKS.—XVI. CONSTANT AND INTERMITTENT SUPPLY.—XVII. DESCRIPTION OF PLATES.—APPENDICES, GIVING TABLES OF RATES OF SUPPLY, VELOCITIES, &c., &c., TOGETHER WITH SPECIFICATIONS OF SEVERAL WORKS ILLUSTRATED, AMONG WHICH WILL BE FOUND: ABERDEEN, BIDEFORD, CANTERBURY, DUNDEE, HALIFAX, LAMBETH, ROTHERHAM, DUBLIN, AND OTHERS.

"The most systematic and valuable work upon water supply hitherto produced in English, or in any other language. Mr. Humber's work is characterised almost throughout by an exhaustiveness much more distinctive of French and German than of English technical treatises." —*Engineer.*

**WATER SUPPLY OF TOWNS AND THE CONSTRUCTION OF WATER-WORKS.** A Practical Treatise for the Use of Engineers and Students of Engineering. By W. K. BURTON, A. M. Inst. C.E., Consulting Engineer to the Tokyo Water-works. Third Edition, Revised. Edited by ALLAN GREENWELL, F.G.S., A.M.Inst.C.E., with numerous Plates and Illustrations. Super-royal 8vo, buckram . . . . **25/0**

I. INTRODUCTORY.—II. DIFFERENT QUALITIES OF WATER.—III. QUANTITY OF WATER TO BE PROVIDED.—IV. ON ASCERTAINING WHETHER A PROPOSED SOURCE OF SUPPLY IS SUFFICIENT.—V. ON ESTIMATING THE STORAGE CAPACITY REQUIRED TO BE PROVIDED.—VI. CLASSIFICATION OF WATER-WORKS.—VII. IMPOUNDING RESERVOIRS.—VIII. EARTHWORK DAMS.—IX. MASONRY DAMS.—X. THE PURIFICATION OF WATER.—XI. SETTLING RESERVOIRS.—XII. SAND FILTRATION.—XIII. PURIFICATION OF WATER BY ACTION OF IRON, SOFTENING OF WATER BY ACTION OF LIME, NATURAL FILTRATION.—XIV. SERVICE OR CLEAN WATER RESERVOIRS—WATER TOWERS—STAND PIPES.—XV. THE CONNECTION OF SETTLING RESERVOIRS, FILTER BEDS AND SERVICE RESERVOIRS.—XVI. PUMPING MACHINERY.—XVII. FLOW OF WATER IN CONDUITS—PIPES AND OPEN CHANNELS.—XVIII. DISTRIBUTION SYSTEMS.—XIX. SPECIAL PROVISIONS FOR THE EXTINCTION OF FIRES.—XX. PIPES FOR WATER-WORKS.—XXI. PREVENTION OF WASTE OF WATER.—XXII. VARIOUS APPLIANCES USED IN CONNECTION WITH WATER-WORKS.

APPENDIX I. By PROF. JOHN MILNE, F.R.S.—CONSIDERATIONS CONCERNING THE PROBABLE EFFECTS OF EARTHQUAKES ON WATER-WORKS, AND THE SPECIAL PRECAUTIONS TO BE TAKEN IN EARTHQUAKE COUNTRIES.

APPENDIX II. By JOHN DE RIJKE, C.E.—ON SAND DUNES AND DUNE SANDS AS A SOURCE OF WATER SUPPLY.

"We congratulate the author upon the practical commonsense shown in the preparation of this work. . . . The plates and diagrams have evidently been prepared with great care, and cannot fail to be of great assistance to the student."—*Builder.*

**WATER SUPPLY, RURAL.** A Practical Handbook on the Supply of Water and Construction of Waterworks for small Country Districts. By ALLAN GREENWELL, A.M.Inst.C.E., and W. T. CURRY, A.M.Inst.C.E., F.G.S. With Illustrations. Second Edition, Revised. Crown 8vo, cloth **5/0**

"The volume contains valuable information upon all matters connected with water supply. It is full of details on points which are continually before water-works engineers."—*Nature.*

**WELLS AND WELL-SINKING.** By J. G. SWINDELL, A.R.I.B.A., and G. R. BURNELL, C.E. Revised Edition. Crown 8vo, cloth . . . . . **2/0**

**WIRELESS TELEGRAPHY: ITS THEORY AND PRACTICE.** A Handbook for the use of Electrical Engineers, Students, and Operators. By JAMES ERSKINE-MURRAY, D.Sc., Fellow of the Royal Society of Edinburgh, Member of the Institution of Electrical Engineers. Second Edition, Revised and Enlarged. 388 pages, with 182 Diagrams and Illustrations. Demy 8vo, cloth . . . . . *Net* **10/6**

ADAPTATIONS OF THE ELECTRIC CURRENT TO TELEGRAPHY—EARLIER ATTEMPTS AT WIRELESS TELEGRAPHY—APPARATUS USED IN THE PRODUCTION OF HIGH FREQUENCY CURRENTS—DETECTION OF SHORT-LIVED CURRENTS OF HIGH FREQUENCY BY MEANS OF IMPERFECT ELECTRICAL CONTACTS—DETECTION OF OSCILLATORY CURRENTS OF HIGH FREQUENCY BY THEIR EFFECTS ON MAGNETISED IRON—THERMOMETRIC DETECTORS OF OSCILLATORY CURRENTS OF HIGH FREQUENCY—ELECTROLYTIC DETECTORS—THE MARCONI SYSTEM—THE LODGE-MUIRHEAD SYSTEM—THE FESSENDEN SYSTEM—THE HOZIER-BROWN SYSTEM—WIRELESS TELEGRAPHY IN ALASKA—THE DE FOREST SYSTEM—THE POULSEN SYSTEM—THE TELEFUNKEN SYSTEM—DIRECTED SYSTEMS—SOME POINTS IN THE THEORY OF JIGS AND JIGGERS—ON THEORIES OF TRANSMISSION—WORLD-WAVE TELEGRAPHY—ADJUSTMENTS, ELECTRICAL MEASUREMENTS AND FAULT TESTING—ON THE CALCULATION OF A SYNTONIC WIRELESS TELEGRAPH STATION—TABLES AND NOTES—RADIOTELEGRAPHIC CONVENTION SERVICE INSTRUCTIONS.

". . . . A serious and meritorious contribution to the literature on this subject. The Author brings to bear not only great practical knowledge, gained by experience in the operation of wireless telegraph stations, but also a very sound knowledge of the principles and phenomena of physical science. His work is thoroughly scientific in its treatment, shows much originality throughout, and merits the close attention of all students of the subject."—*Engineering.*

**WIRELESS TELEPHONES, AND HOW THEY WORK.** By JAMES ERSKINE MURRAY, D.Sc., F.R.S.E., M.I.E.E., Lecturer on Wireless Telegraphy and Telephony at the Northampton Institute, London; Fellow of the Physical Society of London; Author of "Wireless Telegraphy," and Translator of Herr RUHMER'S "Wireless Telephony." 76 pages, with Illustrations and two Plates. Crown 8vo, cloth

[*Just published.* *Net* **1/6**

HOW WE HEAR—HISTORICAL—THE CONVERSION OF SOUND INTO ELECTRIC WAVES—WIRELESS TRANSMISSION—THE PRODUCTION OF ALTERNATING CURRENTS OF HIGH FREQUENCY—HOW THE ELECTRIC WAVES ARE RADIATED AND RECEIVED—THE RECEIVING INSTRUMENTS—DETECTORS—ACHIEVEMENTS AND EXPECTATIONS—GLOSSARY OF TECHNICAL WORDS—INDEX.

**WIRELESS TELEPHONY IN THEORY AND PRACTICE.** By ERNST RUHMER. Translated from the German by J. ERSKINE-MURRAY, D.Sc., M.I.E.E., &c. Author of "A Handbook of Wireless Telegraphy." With an Appendix on Recent Advances by the Translator, and numerous Illustrations. Demy 8vo, cloth . . . . . *Net* **10/6**

"A very full descriptive account of the experimental work which has been carried out on Wireless Telephony is to be found in Professor Ruhmer's book. . . . The volume is profusely illustrated by both photographs and drawings, and should prove a useful reference Work for those directly or indirectly interested in the subject."—*Nature.*

"The explanations and discussions are all clear and simple, and the whole volume is a very readable record of important and interesting work."—*Engineering.*

**WORKSHOP PRACTICE.** As applied to Marine, Land, and Locomotive Engines, Floating Docks, Dredging Machines, Bridges, Ship building, &c. By J. G. WINTON. Fourth Edition, Illustrated. Crown 8vo, cloth . . . . . **3/6**

**WORKS' MANAGER'S HANDBOOK.** Comprising Modern Rules, Tables, and Data. For Engineers, Millwrights, and Boiler Makers; Tool Makers, Machinists, and Metal Workers; Iron and Brass Founders, &c. By W. S. HUTTON, Civil and Mechanical Engineer, Author of "The Practical Engineer's Handbook." Seventh Edition, carefully Revised, and Enlarged. Medium 8vo, strongly bound . . . . . **15/0**

STATIONARY AND LOCOMOTIVE STEAM-ENGINES, GAS PRODUCERS, GAS-ENGINES, OIL-ENGINES, &C.—HYDRAULIC MEMORANDA: PIPES, PUMPS, WATER-POWER, &C.—MILLWORK: SHAFTING, GEARING, PULLEYS, &C.—STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, &C.—HEAT, WARMING, AND VENTILATION—MELTING, CUTTING, AND FINISHING METALS—ALLOYS AND CASTING—WHEEL-CUTTING, SCREW-CUTTING, &C.—STRENGTH AND WEIGHT OF MATERIALS—WORKSHOP DATA, &C.

# PUBLICATIONS OF THE ENGINEERING STANDARDS COMMITTEE.

MESSRS. CROSBY LOCKWOOD and SON, having been appointed OFFICIAL PUBLISHERS to the ENGINEERING STANDARDS COMMITTEE, beg to invite attention to the List given below of the Publications already issued by the Committee, and will be prepared to supply copies thereof and of all Subsequent Publications as issued.

THE ENGINEERING STANDARDS COMMITTEE is the outcome of a Committee appointed by the Institution of Civil Engineers at the instance of Sir John Wolfe Barry, K.C.B., to inquire into the advisability of Standardising Rolled Iron and Steel Sections.

The Committee as now constituted is supported by the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, and the Institution of Electrical Engineers; and the value and importance of its labours—not only to the Engineering profession, but to the country at large—has been emphatically recognised by His Majesty's Government, who have made a liberal grant from the Public Funds by way of contribution to the financial resources of the Committee.

*The Reports are F'cap Folio, Sewed, except where otherwise stated.*

Reports already Published :—

1. **BRITISH STANDARD SECTIONS** (9 lists), *(included in No. 6)*—ANGLES, EQUAL AND UNEQUAL—BULB ANGLES, TEES AND PLATES—Z AND T BARS—CHANNELS—BEAMS *Net* **1/0**
2. **TRAMWAY RAILS AND FISH-PLATES.** *Net* **21/0**
3. **REPORT ON THE INFLUENCE OF GAUGE LENGTH.** By Professor W. C. UNWIN, F.R.S. *Net* **5/0**
4. **PROPERTIES OF STANDARD BEAMS.** *(Included in No. 6.)* Demy 8vo, sewed *Net* **1/0**
5. **STANDARD LOCOMOTIVES FOR INDIAN RAILWAYS** *Superseded.*
6. **PROPERTIES OF BRITISH STANDARD SECTIONS.** Diagrams and Definitions, Tables and Formulæ (British Standard). Demy 8vo, cloth *Net* **2/6**
7. **TABLES OF COPPER CONDUCTORS.** *Net* **5/0**
8. **TUBULAR TRAMWAY POLES.** *Net* **5/0**
9. **BULL-HEADED RAILWAY RAILS.** *Net* **21/0**
10. **TABLES OF PIPE FLANGES.** *Net* **2/6**
11. **FLAT-BOTTOMED RAILWAY RAILS.** *Net* **21/0**
12. **SPECIFICATION FOR PORTLAND CEMENT.** *Net* **5/0**
13. **STRUCTURAL STEEL FOR SHIPBUILDING.** *Net* **5/0**
14. **STRUCTURAL STEEL FOR MARINE BOILERS.** *Net* **5/0**
15. **STRUCTURAL STEEL FOR BRIDGES AND GENERAL BUILDING CONSTRUCTION . . .** *Net* **5/0**
16. **SPECIFICATIONS AND TABLES FOR TELEGRAPH MATERIALS.** *Net* **21/0**
17. **INTERIM REPORT ON ELECTRICAL MACHINERY.** *Superseded.*
19. **REPORT ON TEMPERATURE EXPERIMENTS ON FIELD COILS OF ELECTRICAL MACHINES.** *Net* **10/6**
20. **BRITISH STANDARD SCREW THREADS.** *Net* **2/6**
21. **BRITISH STANDARD PIPE THREADS.** *Net* **2/6**
22. **REPORT ON EFFECT OF TEMPERATURE ON INSULATING MATERIALS.** *Net* **5/0**
23. **STANDARDS FOR TROLLEY GROOVE AND WIRE.** *Net* **1/0**

[P.T.O.

## PUBLICATIONS OF THE ENGINEERING STANDARDS COMMITTEE—(*continued*).

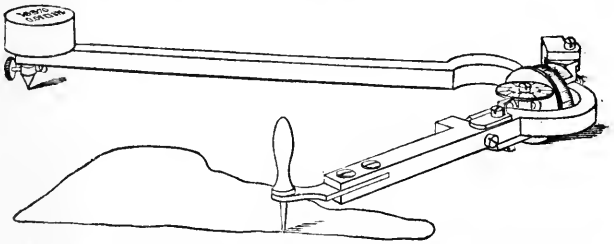
24. MATERIAL USED IN THE CONSTRUCTION OF RAILWAY ROLLING STOCK. *Net* 21/0
25. ERRORS IN WORKMANSHIP. Based on Measurements carried out for the Committee by the National Physical Laboratory *Net* 10/6
26. SECOND REPORT ON STANDARD LOCOMOTIVES FOR INDIAN RAILWAYS. *Superseded.*
27. STANDARD SYSTEMS OF LIMIT GAUGES FOR RUNNING FITS. *Net* 5/0
28. NUTS, BOLT-HEADS, AND SPANNERS. *Net* 2/6
29. INGOT STEEL FORGINGS FOR MARINE PURPOSES. *Net* 5/0
30. INGOT STEEL CASTINGS FOR MARINE PURPOSES. *Net* 5/0
31. STEEL CONDUITS FOR ELECTRICAL WIRING. *Net* 5/0
32. STEEL BARS (for use in Automatic Machines). *Net* 2/6
33. CARBON FILAMENT GLOW LAMPS. *Net* 5/0
35. COPPER ALLOY BARS (for use in Automatic Machines). *Net* 2/6
36. BRITISH STANDARDS FOR ELECTRICAL MACHINERY. *Net* 2/6
37. CONSUMERS' ELECTRIC SUPPLY METERS (Motor Type for Continuous and Single-Phase Circuits). *Net* 5/0
38. BRITISH STANDARD SYSTEMS FOR LIMIT GAUGES FOR SCREW THREADS. *Net* 5/0
39. COMBINED REPORTS ON SCREW THREADS (containing Reports Nos. 20, 28, 38). *Net* 7/6
40. CAST IRON SPIGOT AND SOCKET LOW PRESSURE HEATING PIPES. *Net* 2/6
41. CAST IRON SPIGOT AND SOCKET FLUE OR SMOKE PIPES. *Net* 2/6
42. RECIPROCATING STEAM ENGINES FOR ELECTRICAL PURPOSES. *Net* 5/0
43. CHARCOAL IRON LAPWELDED BOILER TUBES. *Net* 2/6
44. CAST IRON PIPES FOR HYDRAULIC POWER. *Net* 5/0
45. STANDARD DIMENSIONS FOR THE THREADS OF SPARKING PLUGS (FOR INTERNAL COMBUSTION ENGINES). *Net* 2/6
46. KEYS AND KEYWAYS. *Net* 2/6
47. STEEL FISHPLATES FOR BULL-HEAD AND FLAT-BOTTOM RAILWAY RAILS. *Net* 10/6
48. WROUGHT IRON OF SMITHING QUALITY FOR SHIPBUILDING (Grade D.) *Net* 2/6
49. AMMETERS AND VOLTMETERS. *Net* 5/0
50. THIRD REPORT ON STANDARD LOCOMOTIVES FOR INDIAN RAILWAYS. Incorporating Reports Nos. 5 and 26. *Net* 21/0
51. WROUGHT IRON FOR USE IN RAILWAY ROLLING STOCK. "Best Yorkshire," and Grades A., B. and C. *Net* 10/6

**London: Crosby Lockwood & Son,**
**7, STATIONERS' HALL COURT, E.C., and 121a, Victoria Street, S.W.**

BRADBURY, AGNEW, & CO. LD., PRINTERS, LONDON AND TONBRIDGE. (471. 23.9.10.

# W. F. STANLEY & Co., Ltd.,

**MATHEMATICAL INSTRUMENT MANUFACTURERS TO H.M. GOVERNMENT, COUNCIL OF INDIA, SCIENCE AND ART DEPARTMENT, ADMIRALTY, &c.**



PLANIMETER FOR TAKING MEANS OF STEAM DIAGRAMS.

## MATHEMATICAL, DRAWING, AND SURVEYING INSTRUMENTS OF EVERY DESCRIPTION,

**OF THE HIGHEST QUALITY AND FINISH AT THE MOST MODERATE PRICES.**

***ILLUSTRATED PRICE LIST POST FREE.***

W. F. S. obtained the only Medal in the Great Exhibition of 1862 for Excellence of Construction of Mathematical Instruments, and the only GOLD MEDAL in the International Inventions Exhibition, 1885, for Mathematical Work. Silver Medal, Architects' Exhibition, 1886. Gold Medal, Mining Exhibition, 1890, &c., &c.

**STANLEY'S TREATISE ON SURVEYING AND LEVELLING INSTRUMENTS.** 3rd Edition. 562 pages, 372 engravings, post free, 7*s.* 6*d.* Just published.

**STANLEY'S TREATISE ON MATHEMATICAL DRAWING INSTRUMENTS.** 7th Edition. 370 pages, 224 engravings. Post free, 5*s.*

ADDRESS :

## GREAT TURNSTILE, HOLBORN, LONDON, W.C.

Telegrams: "TURNSTILE, LONDON." TELEPHONE No. 65,188.

# PRACTICAL BOOKS

FOR

# PRACTICAL MEN

| | | |
|---|---|---|
| Aerial Navigation (Walker) | net | 7/6 |
| Aerial or Wire-rope Tramways (Wallis-Tayler | | 7/6 |
| Dictionary of Engineering (Lockwood) | net | 7/6 |
| Dynamo Management (Patterson) | | 4/6 |
| Diamond Drilling for Gold and other Minerals (Denny) | | 12/6 |
| Electric Light Fitting (Urquhart) | | 5/- |
| Electrical Dictionary (Sloane) | net | 7/6 |
| Electrical Engineer's Pocket Book (Kempe) | | 5/- |
| Engineering Chemistry (Phillips) | net | 10/6 |
| Engineering Estimates, Costs, and Accounts | | 12/- |
| Engineer's Pocket Book (Clark) | | 6/- |
| Engineer's Year Book (Kempe) | | 8/- |
| Factory Accounts (Garcke and Fells) | | 7/6 |
| Gas Engines (Goodeve) | | 2/6 |
| Gas Engine Handbook (Roberts) | net | 8/6 |
| Hydraulic Power Engineering (Marks) | net | 9/- |
| Lathe Work (Hasluck) | | 5/- |
| Mechanic's Workshop Companion (Templeton) | | 6/- |
| Mechanical Engineer's Companion (Edwards) | | 3/6 |
| Milling Machines and Processes (Hasluck) | | 12/6 |
| Motar-Cars (Wallis-Tayler | | 4/6 |
| Naval Architect's Pocket-Book (Mackrow) | net | 12/6 |
| Pattern Making (Horner) | net | 7/6 |
| Plating and Boiler-making (Horner) | | 7/6 |
| Power Transmitted by Electricity (Atkinson) | net | 9/- |
| Practical Engineer's Handbook (Hutton) | | 18/- |
| Pumps and Pumping (Bale) | | 3/6 |
| Reclamation of Land (Beazeley) | net | 10/6 |
| Stationary Engine Driving (Reynolds) | | 3/6 |
| Steam Boiler Construction (Hutton) | | 18/- |
| Steam Engine (Goodeve) | | 6/- |
| Tables for Mechanics (Smith) | | 1/6 |
| Works Manager's Handbook (Hutton) | | 15/- |

**London: CROSBY LOCKWOOD & SON,**

**7 Stationers' Hall Court, E.C.**

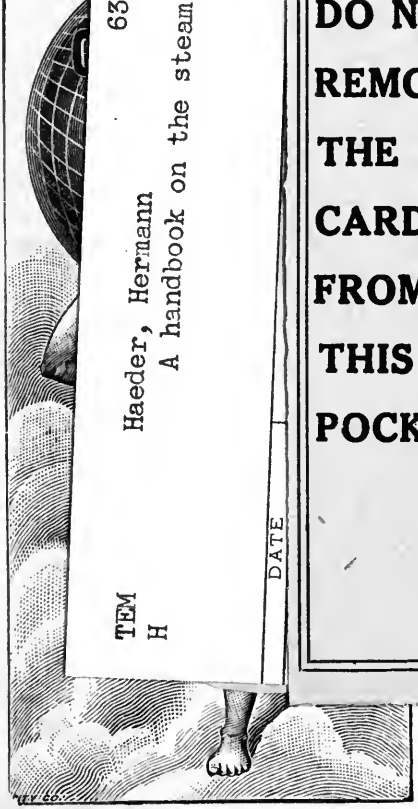
W. H. WILLCOX & CO., LD.

Gen

23, 34

Also a

W



Oils for Willans, Belliss, Bumsted & Chandler, Reavell, and other High-Speed Engines.

UNIVERSITY OF TORONTO LIBRARY

DO NOT REMOVE THE CARD FROM THIS POCKET

635040

Haeder, Hermann
A handbook on the steam engine.

TEM
H

DATE